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Solid Waste Leaching Procedure Manual
Draft Technical Resource Document for
Public Comment

Battelle Columbus Labs., OH

Prepared for

Municipal Environmental Research Lab.
Cincinnati, OH

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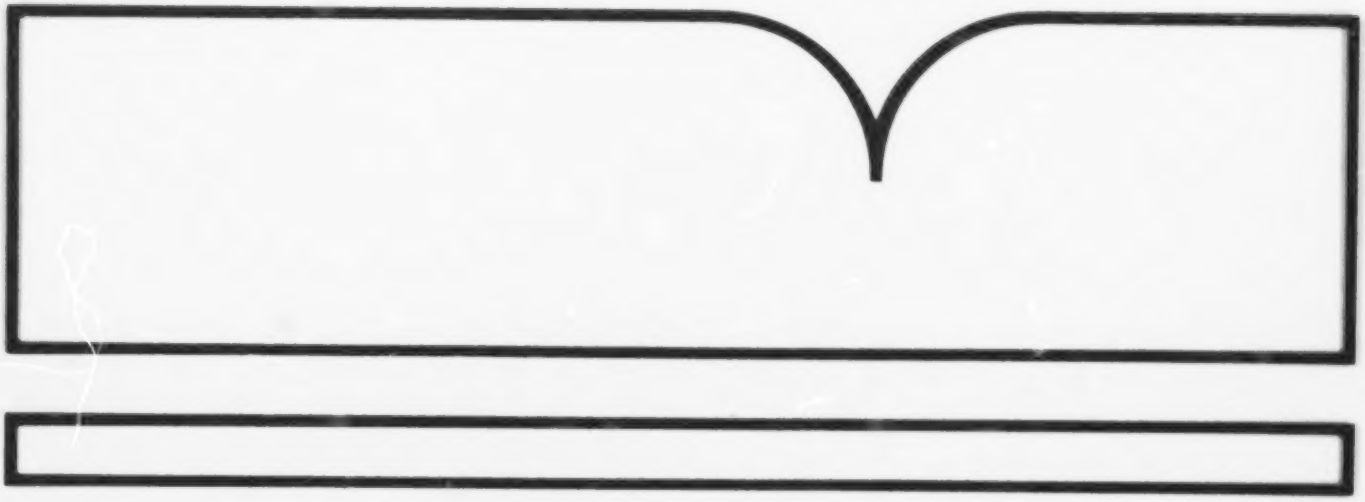

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SOLID WASTE LEACHING PROCEDURE MANUAL

(SW-924)

Draft Technical Resource Document
for Public Comment

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

OFFICE OF SOLID WASTE AND EMERGENCY RESPONSE
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

March 1984

DISCLAIMER

This report was prepared by B. C. Garrett, D. R. Jackson, W. E. Schwartz, and J. S. Warner of Battelle Columbus Laboratories, Columbus, Ohio under Contract 68-03-2970. The EPA Project Officer was M. H. Roulier of the Municipal Environmental Research Laboratory, Cincinnati, Ohio.

This is a draft report that is being released by EPA for public comment on the accuracy and usefulness of the information in it. The report has received extensive technical review but the Agency's peer and administrative review process has not yet been completed. Therefore it does not necessarily reflect the views or policies of the Agency. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

The Environmental Protection Agency was created because of increasing public and governmental concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of the environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is the first necessary step in problem solution; it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and the solid and hazardous waste pollutant discharges from municipal and community sources; to preserve and treat public drinking water supplies; and to minimize the adverse economic, social, health and aesthetic effects of pollution. This publication is one of the products of that research--a vital communications link between the researcher and the user community.

This study examines a laboratory procedure for generating leachate from hazardous industrial solid wastes. The procedure is designed to extract solutes from solid wastes in concentrations representative of those expected to occur in a waste disposal environment.

FRANCIS T. MAYO
Director
Municipal Environmental Research
Laboratory

PREFACE

Subtitle C of the Resource Conservation and Recovery Act (RCRA) requires the Environmental Protection Agency (EPA) to establish a Federal hazardous waste management program. This program must ensure that hazardous wastes are handled safely from generation until final disposition. EPA issued a series of hazardous waste regulations under Subtitle C of RCRA that is published in 40 Code of Federal Regulations (CFR) 260 through 265 and 122 through 124.

Parts 264 and 265 of 40 CFR contain standards applicable to owners and operators of all facilities that treat, store, or dispose of hazardous wastes. Wastes are identified or listed as hazardous under 40 CFR Part 261. The Part 264 standards are implemented through permits issued by authorized states or the EPA in accordance with 40 CFR Part 122 and Part 124 regulations. Land treatment, storage, and disposal (LTSD) regulations in 40 CFR Part 264 issued on July 26, 1982, establish performance standards for hazardous waste landfills, surface impoundments, land treatment units, and waste piles.

The Environmental Protection Agency is developing three types of documents for preparers and reviewers of permit applications for hazardous waste LTSD facilities. These types include RCRA Technical Guidance Documents, Permit Guidance Manuals, and Technical Resource Documents (TRD's). The RCRA Technical Guidance Documents present design and operating specifications or design evaluation techniques that generally comply with or demonstrate compliance with the Design and Operating Requirements and the Closure and Post-Closure Requirements of Part 264. The Permit Guidance Manuals are being developed to describe the permit application information the Agency seeks and to provide guidance to applicants and permit writers in addressing the information requirements. These manuals will include a discussion of each step in the permitting process, and a description of each set of specifications that must be considered for inclusion in the permit.

The Technical Resource Documents present state-of-the-art summaries of technologies and evaluation techniques determined by the Agency to constitute good engineering designs, practices, and procedures. They support the RCRA Technical Guidance Documents and Permit Guidance Manuals in certain areas (i.e., liners, leachate management, closure covers, water balance) by describing current technologies and methods for designing hazardous waste facilities or for evaluating the performance of a facility design. Although emphasis is given to hazardous waste facilities, the information presented in these TRD's may be used in designing and operating non-hazardous waste LTSD facilities as well.

Whereas the RCRA Technical Guidance Documents and Permit Guidance Manuals are directly related to the regulations, the information in these TRD's covers a broader perspective and should not be used to interpret the requirements of the regulations.

This document is a first edition draft being made available for public review and comment It has undergone review by recognized experts in the technical areas covered, but Agency peer review processing has not been completed yet. Public comment is desired on the accuracy and usefulness of the information presented in this manual. Comments received will be evaluated, and suggestions for improvement will be incorporated, wherever feasible, before publication of the second edition. Communications should be addressed to Docket Clerk, Room S-212(A), Office of Solid Waste (WH-562), U.S. Environmental Protection Agency, 401 M Street, S.W., Washington, D.C., 20460. The document under discussion should be identified by title and number (e.g., "Solid Waste Leaching Procedure Manual, SW-924").

ABSTRACT

This manual is a technical guide on one method for providing data on the quality of leachate from solid waste. It describes a batch leaching procedure for use in the laboratory with various kinds of waste to predict the composition of leachate from that waste under field conditions. Methods, equipment, and sources of error are discussed along with suggestions for interpreting the data. The method has not been verified by comparison with field data on leachate composition.

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1.0 INTRODUCTION

An assessment of the composition of leachate from waste entering a disposal facility is useful in reviewing applications for hazardous waste disposal permits. This assessment can provide guidance in designing waste containment and leachate collection and treatment facilities.

This manual describes a solid waste leaching procedure and provides guidelines for use of the procedure on various waste types. The use of this procedure provides an estimate of leachable constituents and the amounts of these constituents that will be released when the waste comes in contact with water in the disposal facility.

1.1 PURPOSE OF STUDY

This procedure was designed to extract leachate having chemical characteristics similar to leachate from the same waste placed in a disposal environment. The procedure is intended to:

1. Characterize the leaching profile of solid waste samples using repetitive leachings with distilled water.

2. Provide integrated data reflective of the type of waste entering a disposal facility and the method of disposal, e.g., landfilling.

3. Provide a cost-effective management tool for assessing leachate quality from a wide variety of solid waste types.

1.2 SCOPE OF MANUAL

This manual was designed to be a technical guide on one method for providing data on leachate quality from solid waste which can be used in disposal facility design and permit review processes.

The manual is designed to be used with the series of Technical Resource Documents (TRDs) which have been prepared on various aspects of hazardous waste disposal for the U.S. EPA-Municipal Environmental Research Laboratory (MERL). This series of TRDs provides technical guidance on moisture infiltration, waste decomposition, leachate generation, disposal facility liners leachate transport and collection, and transport migration and attenuation. The documents in this series are:

TRD 1 Evaluating Cover Systems for Solid and Hazardous Waste (SW-867). This document presents a procedure for evaluating design of final covers on solid and hazardous waste.

TRD 2 Hydrologic Simulation on Solid Waste Disposal Sites (SW-868). This document provides a computer package to aid planners and designers in predicting runoff, evapo-transpiration, and infiltration through landfill covers.

TRD 3 Landfill and Surface Impoundment Performance Evaluation (SW-869). This document describes how to evaluate the capability of various liner/drain designs to control leachate release from landfills.

TRD 4 Lining of Waste Impoundment and Disposal Facilities (SW-870). This document provides information and guidance on the performance, selection, and installation of specific liners for various disposal situations.

TRD 5 Management of Hazardous Waste Leachate (SW-871). This document presents management options for controlling and treating leachate.

TRD 6 Guide to the Disposal of Chemically Stabilized and Solidified Wastes (SW-872). This document provides basic information on stabilization/solidification of industrial waste to reduce leaching and ensure safe burial of waste.

TRD 7 Closure of Hazardous Waste Surface Impoundments (SW-873). This document describes the methods, tests, and procedures involved in closing a site to minimize potential environmental hazards.

TRD 8 Hazardous Waste Land Treatment (SW-874). This document presents and discusses a comprehensive land treatment facility design strategy based on sound environmental protection principles.

This manual will complement the TRD series by providing a means for generating a laboratory leachate similar in composition to that expected from the waste under field conditions.

1.3 BACKGROUND

Difficulties experienced in the past with disposal of hazardous waste can be partially attributed to a lack of knowledge concerning the leachability, compatibility, and the long-term dissolution of various waste forms.

Manifestations of past disposal practices dictate that these factors must be included in evaluating modern hazardous waste disposal facilities. Accurate and reproducible methods for generating and chemically characterizing hazardous waste leachate are needed for the following purposes:

- Performance evaluation of leachate collection and treatment systems for new and existing hazardous waste facilities.

- Assessing the attenuation capacity of various soils and clay minerals for solutes originating from landfilled waste.

- Assessing the compatibility of hazardous waste with earthen and synthetic waste pit liners.

- Developing worst-case scenarios for potential contamination of groundwater resources.

In order to meet the above needs, a solid waste leaching procedure must serve as a model leaching system which will reflect the long-term behavior of the waste in a landfill environment. In addition to this technical requirement, the leaching procedure must be easily performed by technically-trained personnel and cost-effective in analyzing a wide variety of waste types.

In contrast to the EPA Extraction Procedure (EP), which is required by regulation for classifying waste as hazardous or nonhazardous, the Solid Waste Leaching Procedure (SWLP) detailed herein serves only as a guideline for generating leachate from waste. The actual procedure used by a waste generator or other research personnel for generating leachate may deviate from the SWLP when different assumptions and compromises are adopted. Those groups using a different procedure should be prepared to demonstrate that their procedure gives results that are equivalent to the SWLP or are more appropriate for a specific site.

Use of a leaching procedure such as the SWLP dictates significant technical compromises in the interests of simplicity, cost-effectiveness and reproducibility. The most significant of these compromises being:

- A leaching procedure cannot completely anticipate all the slow changes the aging process may induce in the leaching characteristics of the waste in the landfill environment.

- Chemical reactions which occur when leachate from two or more segregated waste cells within a landfill interact cannot be fully simulated by a single component leaching procedure. However, leachate generated from one waste cell type can be used as the leaching medium

for a second waste cell type. This technique was not investigated fully during the development effort that went into preparation of this manual.

- The leaching procedure does not address physicochemical changes in the waste initiated by microbiological processes.

- The leaching procedure may be unsuitable for oily wastes that give leachates having a water-immiscible organic liquid layer. This layer will interfere with obtaining either reproducible or representative leachate fractions.

- The hydrologic regime of the actual field disposal environment (e.g., channeling) may be inadequately addressed by a laboratory leaching procedure.

Although the above compromises may limit the level of interpretation of data obtained from the SWLP, the following design features have been incorporated to increase the usefulness of the test:

- Distilled water is specified as the leaching media to stimulate precipitation inputs to waste disposal facilities.

- Multiple successive extractions are used to evaluate the leaching capacity of the waste and to infer a time-dependent leaching response.

- Reproducibility of test results is enhanced by the mixing action of the rotary extractor.

- The addition of intermittent cover material can be used to simulate the potential interactions that affect the composition of leachate in a disposal facility.

These design features can be contrasted with the EPA EP which has been developed for an entirely different purpose: classification of waste as hazardous or non-hazardous categories. This purpose makes the EP definitional in nature, while the SWLP is designed for evaluation purposes.

A prominent feature that distinguishes the EP from the SWLP is the leaching medium. The EP specifies the use of an acetic acid solution as the leaching medium. This solution may be appropriate for the EP, which was developed in consideration of a worst-case scenario in which hazardous waste is co-disposed with municipal solid waste, but seem inappropriate for the SWLP, which was developed for performance evaluation of properly engineered hazardous waste land disposal facilities from which municipal solid waste would be excluded. Consequently, the SWLP recommends use of distilled water as the leaching medium to simulate precipitation, which would be the predominant liquid entering the fill.

2.0 GENERAL DESCRIPTION OF THE SOLID WASTE LEACHING PROCEDURE (SWLP)

2.1 RATIONALE

Considerable research effort has been expended in an attempt to develop more effective leaching procedures for hazardous solid waste (1,2). Many different procedures have been produced from these efforts. Several complexities associated with developing an extraction test may account for the diversity of procedures now available:

- Correlation of extraction results with on-site observations are difficult, thus verification of extraction methods against a field standard has not been achieved.
- Multiple experimental variables associated with leaching tests, such as leaching media, time of extraction, and type of mixing device, can be manipulated in combination depending on the objectives of the investigator.
- Many waste types (e.g., tars) exist which respond in different ways to a given leaching procedure, requiring that changes be made in some aspect of the procedure to accommodate the unusual characteristics of waste.

The documentation of the SWLP is the culmination of an intensive review of existing extraction procedures and refinements in techniques tested under laboratory conditions. The SWLP is similar to Procedure R of the Standard Leaching Test (SLT) developed by Ham, et al. (1,3) in that both procedures offer the feature of repetitive leaching of hazardous waste samples with fresh aliquots of leaching media. The primary advantage of this feature of the procedure is that an inference of the time-release of leachate can be made. This feature is suggested for use by those researchers desiring a prediction of the leachate composition as a function of time. Guidance is provided for translating extraction sequence number of repetitive leachings into geologic time for the same sample in a specific field environment.

2.2 ASSUMPTIONS AND EXPERIMENTAL PARAMETERS

Three assumptions related to the disposal facility have been made to enhance extrapolation of results obtained from the SWLP to field conditions. The assumptions are that:

(1) the disposal facility practices monofill disposal, (2) the disposal site is designed to isolate segregated wastes, and (3) site meteorological and engineering data are available.

Monofill Disposal

Facilities may take a single type of waste (monofill) or may take a variety of wastes. Current commerical hazardous waste disposal facilities have adopted criteria for waste compatibility. Using these criteria, wastes are segregated into isolated disposal cells to prevent intermingling of incompatible materials. Even after segregation, a cell often contains a number of different wastes. The SWLP has been designed to predict the composition of leachate from a single waste (monofill). Alterations of the procedure are possible to address waste mixtures of various types. For example, leachate generated from one type of waste could be used as the leaching medium for a second type of waste. This example would simulate one type of waste being disposed on top of an existing waste cell.

Site Engineering

A disposal site qualified to accept hazardous waste must be engineered to prevent entry of surface-water runoff from adjacent land and to prevent waste leachate contact with groundwater. The SWLP uses distilled water as the leaching medium to model the assumption that natural precipitation would be the primary leaching medium at the disposal site.

Site Data

The user of this manual is assumed to have access to meteorological and engineering data collected at the site where the solid waste will be disposed. Meteorological data should include average and extreme monthly precipitation volumes and precipitation composition. Engineering data needed are: (1) the expected surface area and depth of the site, (2) the anticipated schedule for disposal activities, and (3) the type of soil used for intermittent cover of the waste. These site data are needed for adequate interpretation of the test results.

The experimental parameters suggested for the SWLP are outlined in Table 1 and are discussed in detail below.

TABLE 1. LEACHING TEST PARAMETERS AND SUGGESTED EXPERIMENTAL SPECIFICATIONS

Leaching Test Parameter	Experimental Specifications	Reference Section Number
Sample	Solid waste + representative amount of intermediate cover soil material	2.2.1
Contact Area/ Particle Size	Surface $\geq$ 3.1 cm^2/g or Sized to pass a 9.5-mm sieve [or Monolithic]	2.2.2
Leaching Medium	Water unless another medium can be justified on a site specific basis	2.2.3
Temperature	Room temperature	2.2.4
Method of Mixing	Rotary mixer (tumbler)	2.2.5
Time of Mixing	18 hours	2.2.6
Number of Leachings Per Sample	Flexible. Four are suggested	2.2.7
Solid to Liquid Ratio	1:10 (1 gram solid to 10 ml liquid)	2.2.8

2.2.1 Sample

A representative sample of the solid waste under consideration for landfill disposal is used together with a sample of soil if any is to be used in the fill as intermittent cover material.

The use of soil in the leaching procedure is a unique feature of the SWLP. This soil should be of the same type and be present in the same proportion as that encountered at the disposal site. The ability of soils to alter the mobility of species in leachates is well known and has been studied extensively for various types of soils and wastes. For example, the extent to which trace inorganic constitutents of leachates are attenuated is related to the amounts of clay and iron and manganese hydrous oxides in the soil (4,5); and attenuation of organic compounds such as PCBs is directly related to the organic carbon content of the soil (6). Furthermore, soil type influences complexing agents and colloidal constituents present in a leachate and soil mixture. Because of the importance of the amount of soil

that is mixed with a solid waste, this procedure recommends including the soil with the waste in the sample to be leached. A possible extension of this procedure is to select the most desirable soil type and determine the optimal proportion to mix with the waste to achieve greatest attenuation of waste solute. Where the solid waste disposal protocol precludes the use of soil during active filling, then no soil should be used with the solid waste sample for leaching.

The effect of various waste/soil mixtures on the amount of constituent that is leached is shown in Figures 1 and 2. These results were obtained from leaching an electroplating waste and a soil taken from a commercially operated industrial waste land disposal facility. Results for calcium (Figure 1) indicate that the addition of soil lowered the equilibrium concentration by 31% using a 50/50 mixture. Additions of soil to the waste had a much greater effect on the attenuation of chromium (Figure 2) by reducing the equilibrium concentration 65% using the 50/50 mixture in the initial extraction sequence. This amount of attenuation implies that the chromium is largely in the trivalent cationic form. In further extractions (extraction sequence numbers 3-6) the chromium concentration tends to increase slightly in combination with soil. This increase most likely is due to chromium oxidation to the hexavalent anionic form which is not highly attenuated by soil. Additional discussion of these results can be found in reference 7. The significance of the results illustrated in Figures 1 and 2 is that the effect of the soil mixed with the waste to form an intermittent or final cover should be anticipated as part of a comprehensive site evaluation. Use of waste/soil mixtures during the leaching test is one aspect of conducting this evaluation.

2.2.2 Contact Area/Particle Size

The contact area of the sample can be $\geq 3.1\ cm^2/g$ or sized to pass through a 9.5-mm standard sieve as specified in the EP, unless the solid waste is monolithic, i.e., composed of massive solidified material. This requirement for contact area and particle size is designed to simulate the likely conditions to be encountered in the field disposal environment due to mechanical filling operations and weathering. Some wastes are naturally monolithic. These wastes will not have their particle size reduced as this would cause them to be more leachable than under field conditions. Any waste passing the Structural Integrity Procedure (as described in reference 8) should be considered to be monolithic and will be tested as a whole rather than at a reduced particle size.

2.2.3 Leaching Medium

Laboratory reagent water is suggested for use as the leaching medium. The water should be free from interferences that might interact with the sample and should conform to one of the grades of Reagent Water consistent with Federal Test Method Standard No. 7916, as given in reference 9. The

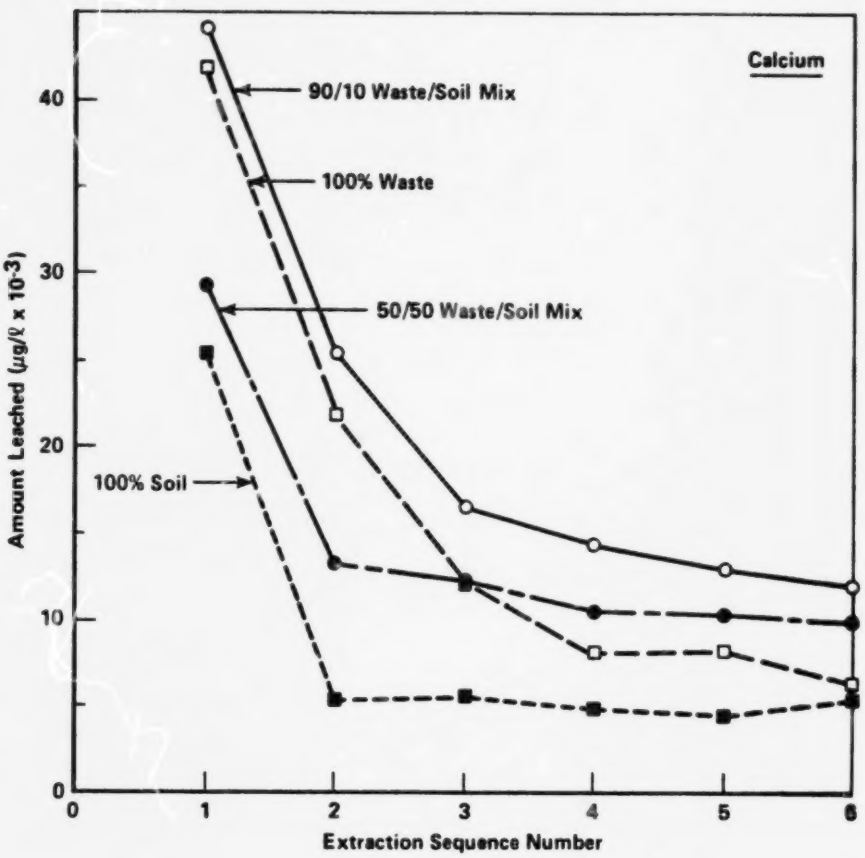

Figure 1. Amount of Calcium Leached from Assorted Waste/Soil Mixtures.

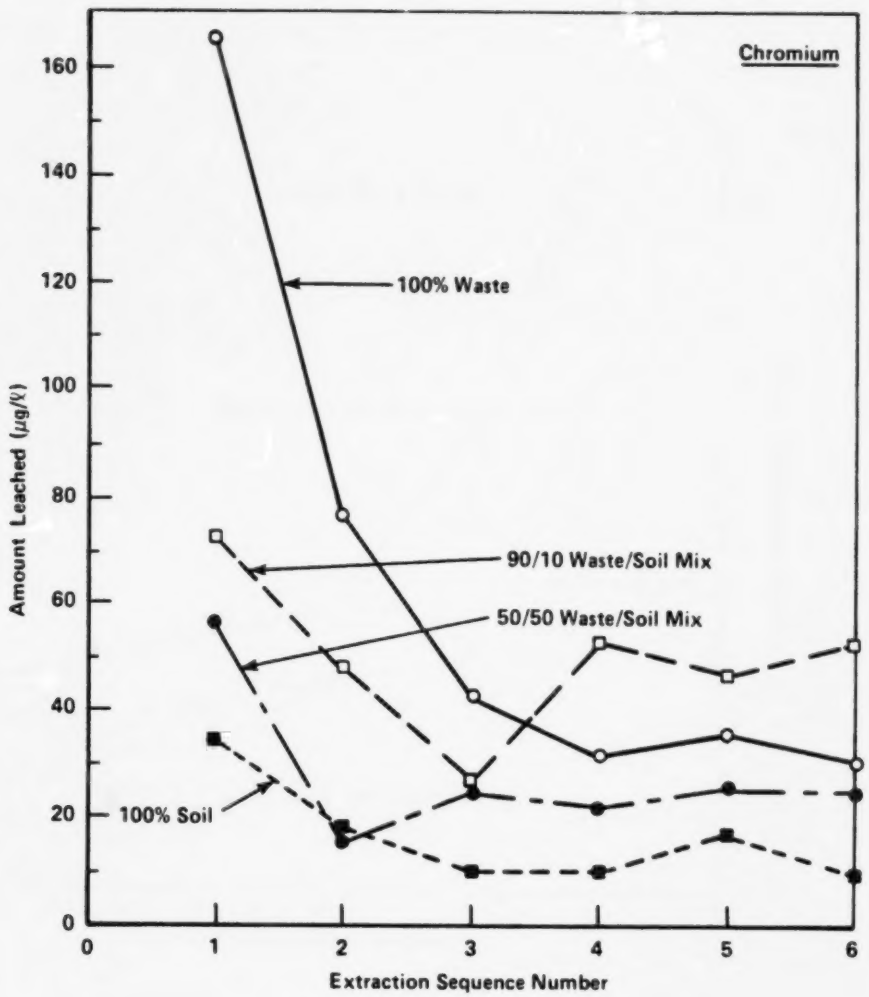

Figure 2. Amount of Chromium Leached from Assorted Waste/Soil Mixtures.

selection of water as the leaching medium is consistent with the assumptions about disposal site design and monofill disposal (no contact with other waste liquids).

2.2.4 Temperature

Although no data are available for determing how much temperature differences may affect waste leaching, temperature is known to affect solubility and reaction rates of many chemical compounds present in waste. Although ambient air temperatures at land disposal sites may range from extreme cold (-40°C) to very high (45°C), temperatures for the leachates associated with these sites are likely to be less varied. Overlying cover soil and waste layers have a dampening effect on temperature variations (10). Consequently, the temperature of the leachate emerging from the bottom of a disposal site is likely to be that of the waste/soil at the same depth. Seasonal fluctuations in waste/soil temperature at various depths may be obtained from disposal site meteorological data or can be measured during preliminary site investigations. The temperature used in the leaching procedure should be close to that expected for the site leachate, unless data are available to show that temperature variances will have little effect on leaching of the waste being studied.

2.2.5 Method of Mixing

Any mixing device can be used for this procedure that will impart sufficient agitation to prevent stratification of the sample suspension and bring into continuous contact with the leaching medium.

The method of agitating or mixing the sample suspension has been studied to determine which method offers the best combination of ease of operation and extent of liquid-solid contact. Several problems have been associated with mechanical stirrers: (1) binding of the stirring blade by solid particles; (2) movement of the stirred vessel; (3) stalling of the stirring motor; (4) uneven blade alignment; and (5) sample grinding (11). However, a stirrer has been designed that in many cases eliminates or reduces these problems (12).

Ham et al. (3) investigated five methods of mixing: mechanical and manual shaking; mechanical stirring; swing shaking (180° swing); and variable pitch rotary mixing. Their results showed comparable levels for inorganic constitutents using the various methods. However, their recommendation was to use a rotary mixer because visual observations indicated that the other mixers occasionally failed to wet the waste uniformly. A study completed for the U.S. EPA comparing the operation of the stirrer and rotary mixer (NBS-design tumbler) indicates the rotary mixer produces greater precision than the stirrer (13). Examples of rotary extractors are shown in Figures 3 and 4.

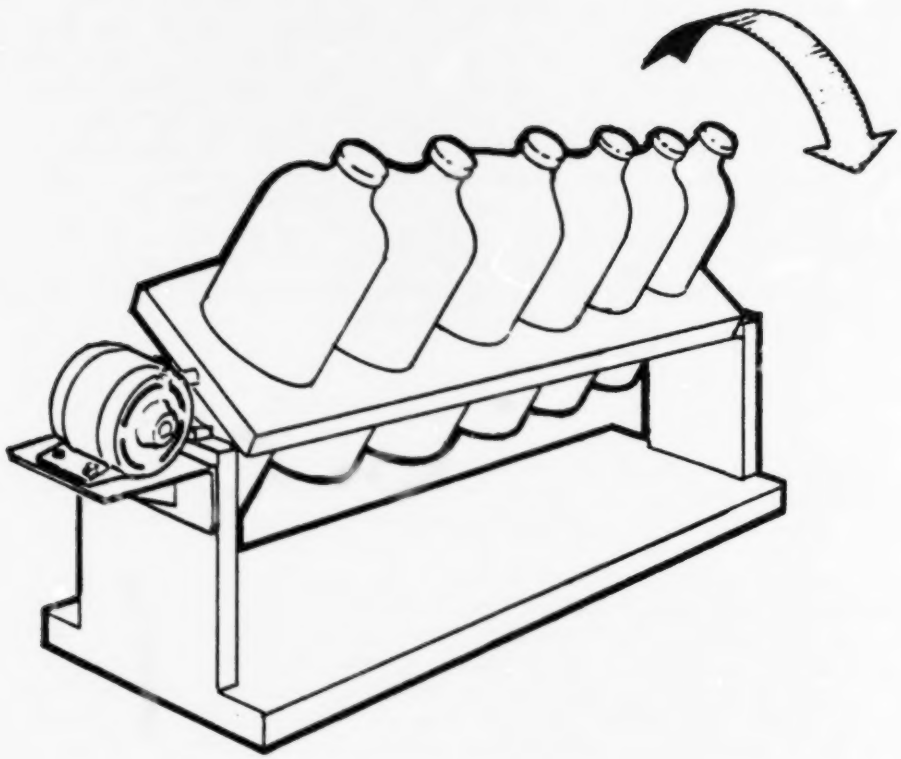

Figure 3. NBS - Design Rotary Extractor

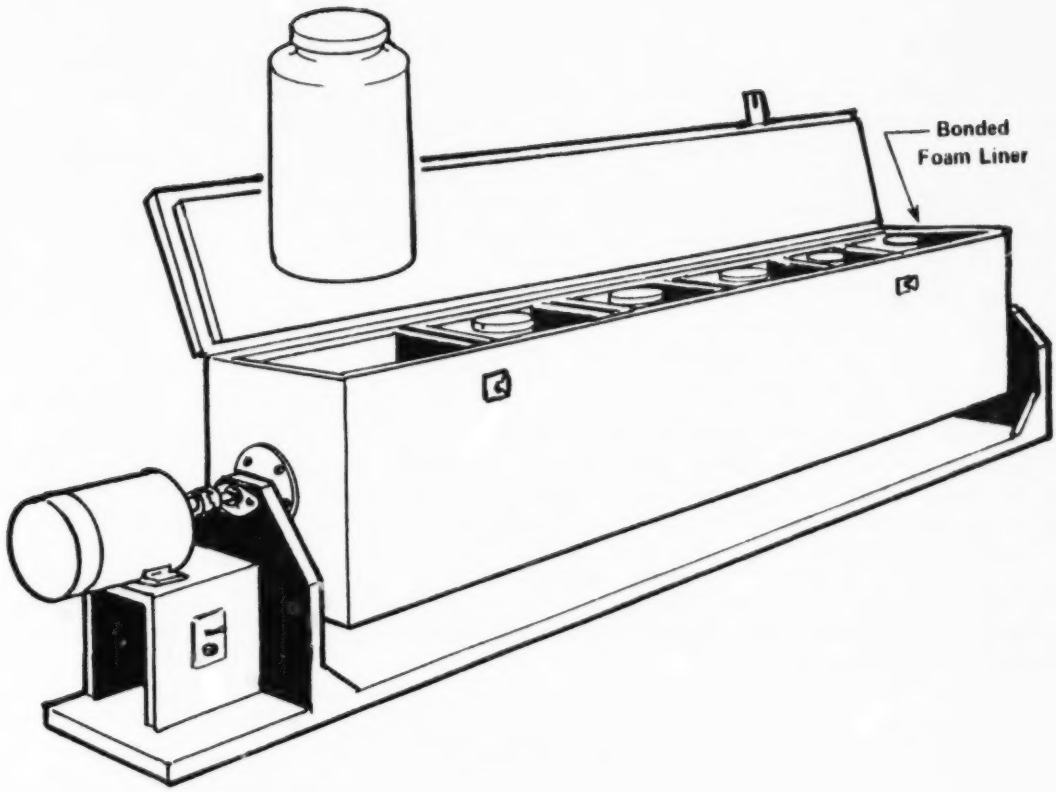

Figure 4. EPRI/Acurex Rotary Extractor

2.2.6 Time of Mixing

The recommended time of mixing is approximately 18 hours. The time specified for each leaching ideally should allow solute equilibrium to be attained. Due to the diversity of waste constituents, no specified mixing time is likely to be satisfactory for all situations. Therefore, the specification of leaching time has to be made out of consideration of factors other than attainment of equilibrium. The recommended time of approximately 18 hours is normally convenient for laboratory scheduling and is consistent with the time specified for other related leaching procedures (2,8).

2.2.7 Number of Leachings

A minimum of four leachings is suggested to allow definite trends in a leachate constituent level (increasing, decreasing, or no change) to be noticeable. The solid waste plus soil sample used for the four leachings is retained pending the analyses of the filtrates and interpretation of the results. In the event the results warrant further leachings, then the leaching cycle can be started with the saved sample and can be continued for as many repetitions as desired.

2.2.8 Solid to Liquid Ratio

The ratio of solid to liquid used for each leaching has been established as 1 to 10 (1 gram per 10 ml). This ratio should provide both an amount sufficient to wet the sample and an excess amount to allow sufficient liquid for proper mixing and subsequent analyses. The solid to liquid ratio that a solid waste will experience in-situ is highly site dependent and very difficult to forecast precisely. In most cases, the ratio will be one of a large amount of solid per unit volume of leachate. The specified ratio does not truly reflect the likely field conditions; rather it is a workable minimum amount that will still allow sufficient liquid for proper mixing and constituent analysis.

2.3 VALIDATION

Leachate collected from an existing solid waste disposal site was compared to leachate generated by the SWLP from corresponding samples of solid waste (7). The purpose of this comparison was to assess the effectiveness of the SWLP in representing leachate obtained under field conditions. Results of this comparison indicated considerable disparity between SWLP-generated leachate and the field-collected leachate. Factors accounting for the observed discrepancies were:

- Non-uniform migration of solutes within the waste profile in the field.

- Limitations of the laboratory method in representing dynamic leaching processes occurring in the waste environment, and

- Depletion of solutes within the waste profile prior to sampling resulting in lower amounts extractable by the SWLP.

For further information on this comparison of labortory and field leachate composition see the description in Appendix C.

Results similar to those obtained in the SWLP validation study described above were obtained in an unrelated study of the leaching behavior of bituminous coal fly ash. In that study, Dodd et al.[14] compared results from extraction procedures to interstitial solution expressed from core samplings and groundwater from the saturated zone of the fly ash disposal pit. Solute concentrations obtained from the two extraction procedures were not generally in good agreement with interstitial solution or groundwater attributed to the inadequacy of the simplified laboratory leaching procedures to account for the complex leaching behavior of the fly ash in the field environment.

The SWLP or similar laboratory leaching tests may or may not provide a completely accurate representation of field-generated leachate. These tests can still be useful in assessing the overall potential leaching of hazardous constituents from a given waste. The use of the SWLP on more waste types and correlations with field leachate will likely provide more validation of the method and confirm how useful it is in evaluating hazardous waste.

Considering the reasons advanced for the disagreement between laboratory predictions of leachate composition and the composition actually observed in the field it is likely that the most definitive validation will be the comparison of leachate from a laboratory test with leachate from the same waste freshly placed in the field. Such a comparison would be further facilitated when the field conditions are known in detail, particularly the depth of waste, density, and rate of moisture infiltration into the waste.

3.0 EXPERIMENTAL

3.1 APPARATUS AND MATERIALS

The apparatus and materials used in the solid waste leaching procedure must be demonstrated to be free from chemical species that might interfere with the analysis of the leachates at the minimum levels of detection. In practice, the apparatus and materials chosen for use in the procedure must be selected with concern for potential interactions between the laboratory equipment and the waste-leachate solution. Examples of interactions to be avoided by careful selection of equipment are:

- Dissolution of the solution container by the leachate, as might happen with a hydrofluoric acid-containing waste placed in a glass vessel,
- Preferential sorption of constituents out of the leachate by the sample container or filtration unit, as might happen with some organic compounds when contained in polypropylene vessels, and
- Contamination of the leachate by constituents leached from the sample container, as might happen with waste leachates to be analyzed for nickel and chromium contained in stainless steel vessels.

The following discussion is designed to guide the investigator in selecting various items for use in the procedure. Specification of a particular manufacturer or model is for purposes of guidance only. Addresses of suppliers referenced in this section can be found in Appendix A.

3.1.1 Extraction Apparatus

An extraction apparatus must avoid stratification of the sample of solid waste and soil and the leaching medium which would inhibit adequate contact between the sample and leachate. The type of extraction apparatus recommended for this procedure is the rotary extractor or tumbler (Figures 3 and 4). The extractor consists of a rack or box device to hold the sample containers, which are rotated through 360° at approximately 30 revolutions per minute.

A six-place tumble extractor derived from a design by the National Bureau of Standards is illustrated in Figure 3. This equipment may be fabricated by the investigator or obtained commercially (Associated Design and Manufacturing Company, model #3740-4-BRE [four-place tumbler] or model

#3740-6-BRE [six-place tumbler]). A second type of six-place tumbler, shown in Figure 4, may be fabricated by the investigator or obtained commercially (Acurex Corporation, no model number available).

The tumbler bottles should be sized to fit the particular tumbler, such as Wheaton model #348522 roller culture vessels or equivalent, 1.8 to 2.5 liter capacity, with an inert cap liner.

3.1.2 Separation Apparatus

Separation of the solid and liquid layers following the extraction of the waste sample can be accomplished by a combination of settling and filtering. Details on performing these manipulations can be found in Section 3.4, which gives stepwise leachate generation instructions.

Filter Holder

The filter holder must be capable of supporting a 0.45 micrometer membrane filter and withstanding the pressure needed to accomplish separation. These units may be simple vacuum units (Millipore model #XX10-047-00; Nuclepore model #410400; or equivalent). However, the units capable of being pressurized up to 75 psi are more likely to be needed for the majority of solid wastes (Millipore model #YT30-142-HW; Nuclepore model #420800; or equivalent).

Filter Pads

Three sizes of filter pads are suggested for use in all filtrations.

(1) Coarse glass fiber prefilter pad (Millipore model #AP25-042-00 or #AP25-127-50 or equivalent)

(2) Fine glass fiber prefilter pad (Millipore model #AP15-042-00 or #AP15-124-50 or equivalent)

(3) 0.45 micrometer nitrocellulose membrane filter (Millipore model #HAWP-047-00 or #HAWP-142-50 or equivalent).

3.1.3 General Labware

Analysis Sample Bottles

The sample bottles used for containing large amounts of waste or leachate should be of suitable materials, such as glass for organic analysis or polypropylene for inorganic analysis; and they should have a screw cap with an inert liner, such as Teflon®.

Sample Vials

Containers for samples for analysis of volatile organic constituents should have approximately 40 ml capacity (Pierce Chemical Company model #13075 or equivalent) and have a screw cap with a Teflon®-faced silicone septum (Pierce model #12722).

3.2 REAGENTS

3.2.1 Leaching Medium

The leaching medium selected for general use in the SWLP is reagent water (9). This water must be of sufficient quality that it is free of organic and inorganic interferences at the minimum levels of interest in the subsequent leaching and leachate analyses that will be performed. Water is the recommended leaching medium because it is deemed the best general leaching medium for simulating natural conditions. An acidic leaching medium or a synthetic leaching medium having a multi-component mixture is not recommended for use with this procedure unless justified on the basis of site-specific information. In certain situations, such as the siting of the potential landfill in an area known to have acid rains, a different medium may be justified. No data are available on the effect of simulated or actual acid rain on leachate composition.

3.2.2 Nitric Acid

Addition of trace metals analysis grade concentrated nitric acid (such as J. T. Baker product #9598 or equivalent) until the mixture has a pH of less than 2 is recommended for preservation of leachate samples after collection for analysis of inorganic constituents.

3.3 SAMPLING

3.3.1 Sample Collection and Handling

A representative sample of the solid waste and soil covered to be tested should be collected using one of the methods described in reference 8. It is particularly important that the sample be representative of the solid waste as it occurs in a landfill environment.

A minimum sample of 5 kg should be collected and sent to the laboratory in a sealed container or containers. The container must be of suitable material such that it will not react with the waste. In many cases a polypropylene container will be inert to the waste and, hence, adequate for use. However, the suitability of the container should be assessed in light of the likely composition of the waste.

3.3.2 Sample Preservation

Samples that are stabilized with regard to biological or chemical change may be shipped and stored at room temperature. Samples that are not stabilized and might undergo significant biological or chemical change at room temperature must be maintained at 0-5°C, during shipping and storage. If the stability of the waste or soil is uncertain or unknown, shipping and storage of the waste at 0-5°C is recommended.

Leaching of samples should be initiated within one week of sample collection to preclude gross changes in sample composition with storage time, unless the sample is known to be stable to potential changes in composition.

3.4 LEACHATE GENERATION

The overall flow scheme for the SWLP is shown in Figure 5. Detailed laboratory procedures are outline below.

3.4.1 Extraction 1

Step 1 Mixture Preparation

Place a 100-g representative sample of the solid waste and soil that has been prepared for testing (see comments in Section 2.2.1) in an extraction vessel (tumbler bottle or equivalent container). Add one liter of leaching medium (Section 2.2.8) to the extraction vessel.

Step 2 Tumbling

Tighten the cap on the vessel and mix by tumbling, using the rotary extractor. Tumble for 18 (±2) hours at room temperature. Stop the rotary extractor, remove the extraction vessel, and allow the mixture to settle for 15 minutes.

Step 3 Sampling for Volatile Organic Constituents

If a sample of the leachate is needed for analysis of volatile organic constituents, the aliquot should be withdrawn prior to filtration. Obtain a sample for volatile organic constituent analysis by completely filling a 40 ml sample vial with the leachate. Fill the sample vial in such a manner that no air bubbles pass through the sample as the vial is being filled and no air space remains in the vial. Seal the vial with a Teflon®-faced septum and screw-cap. Store it at 0-5°C in an inverted position until the time for analysis. The sample container should be labelled to include the date, extraction sequence number, and an appropriate sample identification number.

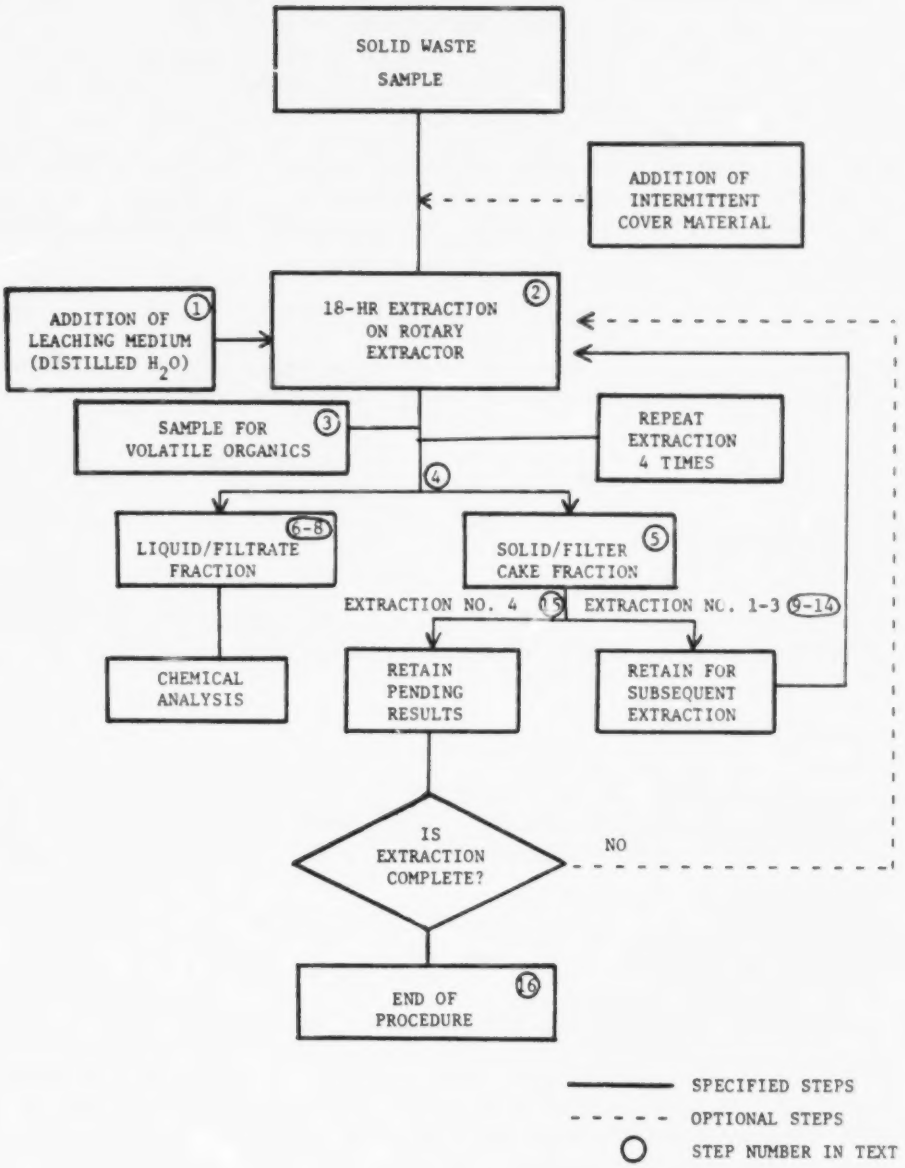

Figure 5. Schematic Diagram of the Overall Solid Waste Leaching Procedure (SWLP).

If a discrete water-immiscible layer is present, withdraw the layer using a syringe with a wide-bore needle. Transfer the layer to a tared sample container of suitable material, such as glass. Determine the mass of the layer and analyze it separately.

Step 4 Separation

Assemble the filter holder and filter pads following the manufacturer's instructions. Place the 0.45 micrometer nitrocellulose membrane filter pad on the support screen of the filter holder. Add first the fine glass fiber prefilter pad and place the coarse glass fiber prefilter pad on top of the membrane pad, so that the coarse pad will be the one closest to the filter cake.

After assembling the filtration apparatus, wet the uppermost filter pad with a small portion of the liquid phase of the extraction mixture. Transfer the remainder of the extraction liquid layer to the filtration unit. Take care to avoid transferring much of the solid from the extraction vessel, because substantial amounts of solid can clog the filter pads. Apply vacuum or gentle pressure (10 to 15 psi) until all liquid passes through the filter.

Stop the filtration when all the liquid has passed through the filter pads. If this point is not reached under vacuum or using gentle pressure, then increase the pressure stepwise in 10 psi increments to a final maximum pressure of 75 psi.

If liquid remains above the filter pads after 30 minutes of filtration at 65 psi, halt the filtration by slowly venting the pressurizing gas. Be certain to follow the manufacturer's instructions for venting a pressurized filtration apparatus. Some liquid may be trapped in the vent port and may be released. Care must be taken to direct the vent port away from laboratory personnel. After venting, decant the liquid above the filter pads into a suitable container. Place the top-most (coarse) prefilter pad plus any solid/filter cake in a suitable container, such as the extraction vessel for use in the next extraction. Replace the filter pads, placing the fresh pads on the unit in the correct order, and resume filtering.

Repeat the process of replacing the filter pad as often as necessary until all the liquid has been filtered. In each process, retain the top-most (coarse) prefilter pad along with any solid/filter cake.

After halting the filtration, return the unit to atmospheric pressure by either carefully breaking the vacuum or slowly venting the filtration apparatus.

Step 5 Solid/Filter Cake

Retain the solid/filter cake after filtration for use in the next extraction or pending the interpretation of the results obtained from the procedure. Include the top-most (coarse) prefilter pad for all filtrations, as stated in Step 4. Use tweezers made of or coated with an inert material to break apart the filter pads prior to beginning the next extraction.

Step 6 Sample for pH and
Inorganic Constituents Analyses

Transfer an aliquot of the liquid/filtrate from Step 4 to a suitable container, such as a beaker. Determine the pH. If an analysis for inorganic constituents is needed, add a minimum volume of nitric acid (see Section 3.2.2) to lower the pH to less than 2. Transfer the acidified sample to a suitable container, such as a screw-cap polypropylene bottle. Store at room temperature prior to analysis. The sample container must be labelled properly, to include the date, extraction sequence number, and an appropriate sample identification number.

Step 7 Sample for Semivolatile
Organic Constituents Analysis

Transfer an aliquot of the liquid filtrate from Step 4 to be used for semivolatile organic constituents analysis to a suitable container, such as a glass bottle with an inert-lined screw-cap. Store the sample at 0-5°C prior to analysis. The sample container must be labelled properly, to include the date, extraction sequence number, and a appropriate sample identification number.

Step 8 Remainder of Filtrate

Retain any remaining filtrate after samples have been removed for analysis. After analyses are complete, dispose of the filtrate in accordance with approved laboratory procedures for disposal of potentially hazardous liquids.

3.4.2 Extraction 2

Step 9 Mixture Preparation

Place the solid/filter cake from Extraction 1 (Step 5) with the coarse filter pad or pads in an extraction vessel. Add one liter of fresh leaching medium to the extraction vessel.

Step 10

Repeat the process of Step 2 through Step 8 using the previously extracted solid waste plus fresh leaching medium mixture.

3.4.3 Extraction 3

Step 11 Mixture Preparation

Place the solid/filter cake from Extraction 2 with the coarse filter pad or pads in an extraction vessel. Add one liter of fresh leaching medium to the extraction vessel.

Step 12

Repeat the process of Step 2 through Step 8 using the previously extracted solid waste plus fresh leaching medium mixture.

3.4.4 Extraction 4

Step 13 Mixture Preparation

Place the solid/filter cake from Extraction 3 with the coarse filter pad or pads in an extraction vessel. Add one liter of fresh leaching medium to the extraction vessel.

Step 14

Repeat the process of Step 2 through Step 8 using the previously extracted solid waste plus fresh leaching medium mixture.

Step 15 Retention of Solid/Filter Cake

Retain the solid/filter cake from Extraction 4 pending a decision on the need for further extractions.

3.4.5 Further Extractions

The need for further extractions is determined based on the interpretation of results. Depending on the amount of solid waste that is dissolved on each extraction, the extraction of the same solid waste sample with fresh leaching medium can be repeated until solute concentrations reach minimal detection levels.

Step 16 Disposal of the Solid/Filter Cake

After all laboratory testing has been completed, the solid/filter cake should be discarded in accordance with approved laboratory procedures for disposal of potentially hazardous wastes.

3.5 ANALYSIS

The samples collected for analysis should be analyzed by one of the EPA-approved or EPA-proposed methods. These methods can be found in a variety of references (1,15,16).

4.0 QUALITY CONTROL

4.1 INTRODUCTION

Quality control for the solid waste leaching procedure involves two aspects: (1) that the procedure is free of interferences and ensures reliability of the results, and (2) that the procedure is monitored while underway to ensure that the desired level of quality is being achieved.

Guidelines presented in this section are designed to help the investigator fulfill these two aspects of quality control. The basic method used is to process procedure blanks through the various steps in the procedure. These blanks are analyzed to determine whether interferences appear. The analytical results are used to either modify the procedure, to eliminate the source of the interferences, or correct the solid waste sample results for background levels. Replicate samples are processes to monitor the precision and accuracy of the procedure.

At present, no hazardous solid waste reference material is available, although reference materials for nonhazardous wastes do exist. Consequently interlaboratory comparisons of results from using the procedure on a standard reference material representing hazardous wastes are not possible.

4.2 LEACHATE GENERATION

4.2.1 Preliminary

Before any solid waste sample is tested using the solid waste leaching procedure, demonstrate that the procedure is free from any analytical interference by processing procedure blanks through the various steps.

QC Step 1 Mixture Preparation

Using a graduate cylinder, add one liter of the leaching medium to an extraction vessel containing no solid waste sample.

QC Step 2 Tumbling

Tighten the cap on the vessel and mix by the rotary extractor or selected alternative method. Mix for 18 (±2) hours at room temperature. Stop the rotary extractor, remove the extraction vessel, and allow the mixture to settle for 15 minutes.

QC Step 3 Separation

Prepare the filtration apparatus by the method of Step 4, Section 3.4.1. Filter the extraction mixture in the same manner as that to be used with the solid waste samples.

QC Step 4 Sampling for Analysis

Remove aliquots of the procedure blank solution for each type of analysis to be run on the solid waste sample (analysis for pH, inorganics, and volatile and semivolatile organic constituents). If sampling for volatile organic analysis is done, follow the method of Step 3, Section 3.4.1, for filling the sample vial. Label all sample containers, to include date and appropriate sample identification number.

QC Step 5 Results

Examine the results of the analyses and determine whether any interferences are present. Identify the likely sources of the interferences and modify the procedure accordingly. Repeat the processing of a procedure blank on the modified procedure until the interferences have been eliminated.

4.2.2 Sample Testing

QC Step 6 Procedure Blank

The procedure blank consists of the leaching medium with no waste added. It is recommended that one procedure blank be processed for every batch or every ten solid waste samples tested. Carry the procedure blank through the same steps as the solid waste sample. Ensure that the procedure blank is treated identically to the solid waste sample. Be certain to add the topmost (coarse) prefilter pad from Step 4, Section 3.4.2, to the successive blanks that are generated.

QC Step 7 Replicate Sampling

Triplicate analysis of solid waste samples is recommended to obtain a standard deviation indicative of the variability associated with the analysis.

5.0 CONVERSION AND INTERPRETATION OF EXPERIMENTAL DATA

5.1 DATA CONVERSION

Conversion of the experimental data obtained in the leaching experiments is necessary to predict the waste leaching characteristics under field conditions. For interpretative purposes, the experimental data can be related to concentration and mass of released waste constituents; or with pertinent assumptions, as the constituents release into leachate as a function of time. Statistical treatment of these data is shown in Appendix B.

5.1.1 Concentration and Mass Release Conversions

Conversion of the experimental data generated by the implementation of the SWLP can be made in terms of (1) concentration of constituents in leachate, (2) the mass of constituents released from each extraction, and (3) the cumulative mass of released constituents. The following discussion describes methods and examples for converting data into each of the above forms.

5.1.1.1 Calculation of Concentration

The data obtained using this SWLP can be used directly in terms of the concentration of the constituent that was found on analysis of the leachate solution. The general method of calculating this concentration is given in Equation 1.

$$C(x)_i = C(anal)_i \times DF \qquad \text{Equation 1}$$

In this equation, $C(x)_i$ is the concentration of constituent x in the leachate solution from extraction sequence number i and has the dimensions of mass of x per unit volume of leachate. $C(anal)_i$ is the concentration of x that was found on analysis. DF represents the dilution factor or concentration factor for the analysis. The dilution factor gives the extent to which the leachate solution was diluted or concentrated prior to analysis.

5.1.1.2 Calculation of Mass Released Per Extraction

The mass of the constituent released from the solid waste sample for each extraction can be calculated by the method given in Equation 2.

$$M(x)_i = \frac{C(x)_i}{S:L} \qquad \text{Equation 2}$$

In this equation, $M(x)_i$ is the mass of constituent x that was released from the solid waste sample during extraction sequence number i. The term S:L is the solid to liquid ratio used in the extraction. The volume in the denominators of both $C(x)_i$ and S:L must be in the same units, such as liters or milliliters so that these units will cancel. The term $M(x)_i$ will then have the dimensions of mass of x released per unit mass of solid waste, such as mg of x per g of waste.

5.1.1.3 Calculation of Cumulative Mass Released

The data can be used to calculate the cumulative mass of a constituent released from the solid waste during a series of extractions. The general method for calculating cumulative mass released is given in Equation 3.

$$M(x)_{cum} = \sum_{i=1}^{n} M(x)_i \qquad \text{Equation 3}$$

In this equation, $M(x)_{cum}$ is the cumulative mass of constituent x per unit mass of waste that was released over the number of extractions (n). An example is presented in Table 4.

5.1.1.4 Compilation of Concentration and Mass Release Calculations

A data set of concentration and mass release calculations for a series of four extractions on one waste sample is presented in Table 4. These data are representative of data obtained during experimental development of this leaching procedure.

TABLE 2. CONVERSION OF EXPERIMENTAL DATA

Extraction Sequence Number	$C(anal)_i$ (mg/l)	DF	$C(x)_i$ (mg/l)	$M(x)_i$ (mg/g)	$M(x)_{cum}$ (mg/g)
1	4.6	2.0	9.2	0.092	0.092
2	3.8	1.0	3.8	0.038	0.130
3	2.8	1.0	2.8	0.028	0.158
4	2.0	0.5	1.0	0.010	0.168

The results calculated above can also be presented graphically. The graphs can be prepared to show the extraction sequence number versus either the concentration of constituent in the leachate solution or the mass released from the solid waste. Examples of graphing of results are shown in Figure 6 which presents the data from Table 4.

5.1.2 Calculation of Time Required for Leaching

The amount of time required in the field to collect a volume of leachate comparable to that in each leaching sequence can be computed from the experimental data assuming the following:

- Primary leachate volume is disregarded.[1]
- Water infiltration rate through waste is constant, controlled by the permeability of the cap material, and is independent of the pore space of the waste.
- Depth of waste is fixed and known.
- The concentration of solutes in the waste does not change over time.
- Waste is a monofill and is saturated with water at the time of disposal.

[1] Some wastes, as disposed, contain interstitial liquids having high concentrations of solutes which may be displaced as undiluted leachates early in the leaching process. This leachate has been classified as primary in contrast to secondary leachate which is reflective of solutes dissolved in perculating water of external origin, such as precipitation (17).

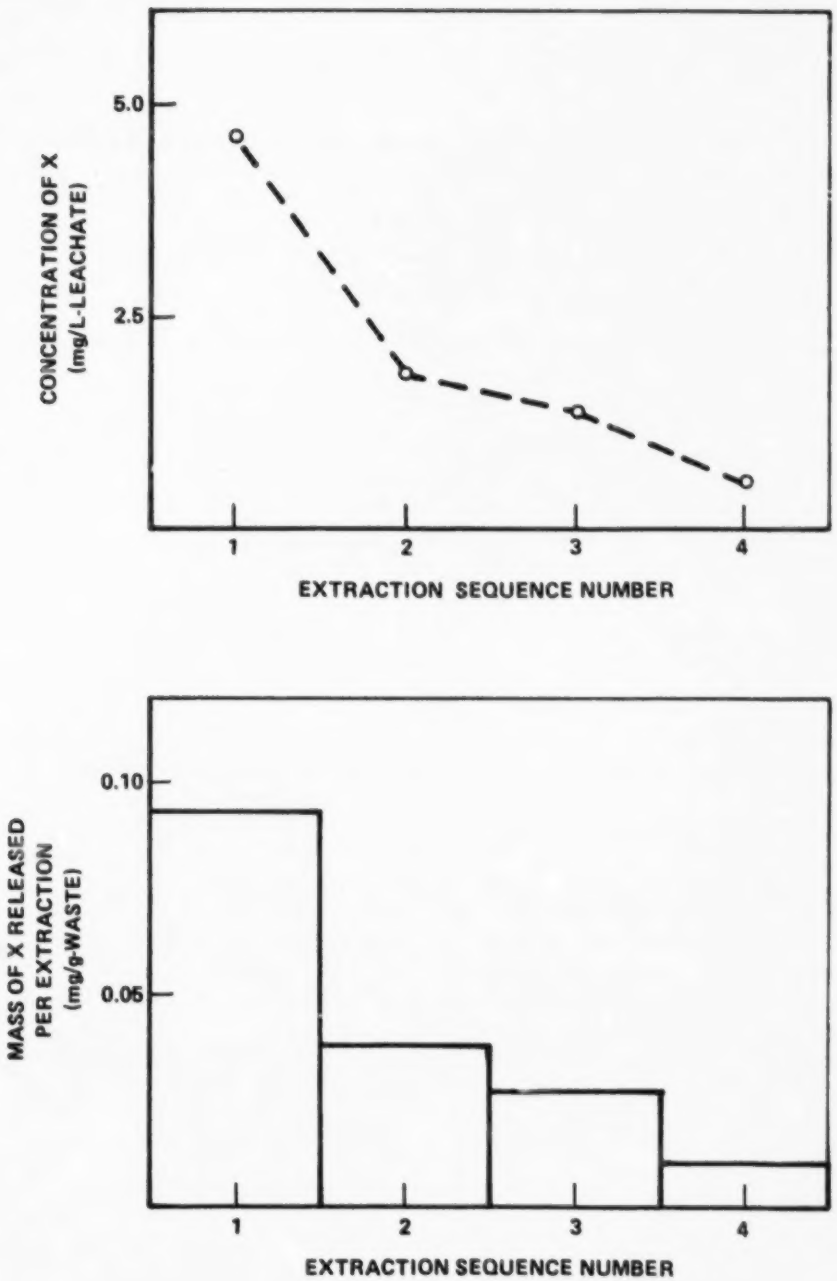

Figure 6. Constituent Profile for Sample Data in Table 4.

Based on these assumptions, the equation for calculating the time corresponding to each leaching fraction is presented below.

$$LT = (DW \cdot \rho_{waste} \cdot LSR) \div (CP \cdot \rho_{water}) \qquad \text{Equation 4}$$

where:

LT = Leaching time (years to exceed leaching sequence)
DW = Depth of fill (m, ft)
ρ_{waste} = Density of waste (g/cm^3, lb/ft^3)
LSR = Liquid to solid ratio of SWLP
CP = Permeability of cap material (cm/sec, ft/year)
ρ_{water} = Density of water (g/cm^3, lb/gal)

A representative case has been devised to illustrate use of this equation. Let:

DW = 6.1 m (20 ft)
ρ_{waste} = 1.3 g/cm^3 (74.7 lb/ft^3)
LSR = 10
CP = $1x10^{-7}$ cm/sec ($1x10^{-1}$ ft/yr)
= $1x10^{-7}$ $ml/sec \cdot cm^2$ (0.77 $gal/yr \cdot ft^2$)
ρ_{water} = 1.0 g/cm^3 (8.39 lb/gal)

LT = (20 ft·74.7 lb/ft^3·10) ÷ (0.77 $gal/yr \cdot ft^2$·8.39 lb/gal)
≃ 2,000 years

Thus, the leaching time in the field corresponding to the first leaching sequence is 2000 years using the $1x10^{-7}$ cm/sec permeability value.

The usefulness of this computation is illustrated in Table 3. Calculations are presented for four leaching sequences and five cap permeability values. For example, the time corresponding to the first extraction sequence ranges from 20 years to 200,000 for cap permeabilities of 10^{-5} cm/sec and 10^{-9} cm/sec, respectively, at a depth of waste fill of 6.1 m. The results of these time calculations, as shown in Table 3, demonstrate the extremely long time (in terms of landfilll life) associated with each extraction sequence. In most cases, the initial extraction sequence will provide the leachate fraction of prime interest. These calculations presume that the cap permeability determines the flow of leachate through the fill.

TABLE 3. TIME CORRESPONDING TO SPECIFIC EXTRACTION SEQUENCE FOR SELECTED CAP PERMEABILITIES (DEPTH OF WASTE = 6.1 m (20 ft))

Extraction Sequence Number	Time Corresponding to Sequence at Selected Cap Permeabilities				
	10^{-5} cm/s	10^{-6} cm/s	10^{-7} cm/s	10^{-8} cm/s	10^{-9} cm/s
	Years				
1	20	200	2000	20,000	200,000
2	40	400	4000	40,000	400,000
3	60	600	6000	60,000	600,000
4	80	800	8000	30,000	800,000

5.2 INTERPRETATION

In general, the interpretation of the results involves comparisons of the concentration of mass-released profiles of the various constituents that have been examined. The Technical Resource Documents (TRDs) discussed in Section 1 provide guidance on leachate flow rate calculations (see in particular TRD2, "Hydrologic Simulation on Solid Waste Disposal Sites [SW-868]," TRD3, "Landfill and Surface Impoundment Performance Evaluation [SW-869]," and TRD5, "Management of Hazardous Waste Leachate [SW-871]"). These documents plus the studies on leachate generation by Houle and Long (18,19) are additional sources for information on calculations and interpretation of leachate test data.

The profile illustrated in Figure 6 may be encountered when the constituent is steadily depleted from the solid waste. Each subsequent extraction releases more of the constituent, although the mass released per extraction decreases with each extraction. Other profiles that might be encountered would show such trends as (1) a steady release where each extraction releases essentially the same amount and (2) a delayed release where initially little or none of the constituent was released, followed by large increases in the amount released when alkalinity is leached and pH decreases allowing metals to go into solution.

A decision regarding the need for further extractions will depend on the profiles obtained for the initial sequence of extractions plus the specific needs of the research being conducted. The application of the results to events in a landfill environment depends on site specific information such as infiltration rate for rainfall, the permeability of the waste, and the density of the waste.

6.0 REFERENCES

1. Ham, R. K., M. A. Anderson, R. Stanforth and R. Stegmann. The Development of a Leaching Test for Industrial Wastes. In: Land Disposal of Hazardous Wastes, Proceedings of the Fourth Annual Research Symposium, San Antonio, Texas, March 6-8, 1978. EPA-600/9-78-016, U. S. Environmental Protection Agency, Cincinnati, ohio, 1978. pp 33-46.

2. Lowenbach, W. Compilation and Evaluation of Leaching Test Methods, EPA-600/2-78-095, U. S. Environmental Protection Agency, Cincinnati, Ohio, 1978. 111 pp.

3. Ham, R., M. A. Anderson, R. Stegmann, and R. Stanforth. Background Study on the Development of a Standard Study on the Development of a Standard Leaching Test, EPA-600/2-78-109, U. S. Environmental Protection Agency, Cincinnati, Ohio, 1979. 274 pp.

4. Fuller, W. H. Investigation of Landfill Leachate Pollutant Attenuation by Soils, EPA-600/2-78-158, U. S. Environmental Protection Agency, Cincinnati, Ohio, 1978. 239 pp.

5. Griffin, R. A., and N. F. Shrimp. Attenuation of Pollutants in Municipal Landfill Leachate by Clay Minerals, EPA-600/2-78-157, U. S. Environmental Protection Agency, Cincinnati, Ohio, 1978. 157 pp.

6. Griffin, R. A., and E. S. K. Chian. Attenuation of Water-Soluble Polychlorinated Biphenyls by Earth Materials, EPA-600/2-80-027, U. S. Environmental Protection Agency, Cincinnati, Ohio, 1980. 101 pp.

7. Garrett, B. C., J. S. Warner, M. P. Miller, and L. G. Taft. Laboratory and Field Studies of Factors in Predicting Site Specific Composition of Hazardous Waste Leachate. In: Land Disposal of Hazardous Waste: Proceedings of the Eighth Annual Research Symposium. EPA-600/9-82-002, U. S. Environmental Protection Agency, Cincinnati, Ohio, 1982. pp 67-86.

8. Office of Solid Waste, Test Methods for Evaluating Solid Wastes, SW-846, U. S. Environmental Protection Agency, Washington, D. C., 1980.

9. ASTM D1193-77. 1980 Annual Book of Standards, Part 31: Water, American Society for Testing Materials, Philadelphia, Pennsylvania.

10. Fluker, B. J. Soil Temperature. Soil Sci., 86:35-46, 1958.

11. Epler, J. L., et al. Toxicity of Leachates. IAG No. DOE-IAG-40-646-77/ EPA-IAG-78-D-X0372, Interim Progress Report to U. S. Environmental Protection Agency, Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1979.

12. Epler, J. L., et al. Toxicity of Leachates. EPA-600/2-80-057, U. S. Environmental Protection Agency, Cincinnati, Ohio, 1980. 142 pp.

13. Warner, J. S., B. J. Hidey, G. A. Jungclaus, M. M. McKown, M. P. Miller, and R. M. Riggin. Determining the Leachability of Organic Compounds from Solid Wastes. In: Hazardous Solid Waste Testing: First Conference, ASTM STP 760, R. A. Conway and B. C. Malloy, Eds., American Society for Testing and Materials, 1981. pp. 40-60.

14. Dodd, D. J. R., A. Golomb, H. T. Chan, and D. Chartier. A Comparative Field and Laboratory Study of Fly Ash Leaching Characteristics. In: Hazardous Solid Waste Testing: First Conference, ASTM STP 760. R. A. Conway and B. C. Malloy, Eds., American Society for Testing and Materials, 1981. pp 164-185.

15. U. S. Environmental Protection Agency. Guidelines Establishing Test Procedures for the Analysis of Pollutants: Proposed Regulations, Federal Register, 44:69464-69575, 1979.

16. Kopp, J. F., and G. D. McKee. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020, U. S. Environmental Protection Agency, Cincinnati, Ohio, 1979. 460 pp.

17. Brown, K. W., and D. Anderson. Effect of Organic Chemicals on Clay Liner Permeability. In: Disposal of Hazardous Waste: Proceedings of the Sixth Annual Research Symposium, EPA-600/9-80-010, U. S. Environmental Protection Agency, Cincinnati, Ohio, 1980. pp 123-124.

18. Houle, M. J., and D. E. Long. Accelerated Testing of Waste Leachability and Contaminant Movement in Soils. In: Land Disposal of Hazardous Wastes, Proceedings of the Fourth Annual Research Symposium, at San Antonio, Texas, March 6-8, 1978. EPA-600/9-78-016, U. S. Environmental Protection Agency, Cincinnati, Ohio, 1978. pp 152-168.

19. Houle, M. J., and D. E. Long. Interpreting Results from Serial Batch Extraction Tests of Wastes and Soils. In: Disposal of Hazardous Waste, Proceedings of the Sixth Annual Research Symposium, at Chicago, Illinois, March 17-20, 1980. EPA-600/9-80-010. U. S. Environmental Protection Agency, Cincinnati, Ohio, 1980. pp 60-81.

APPENDIX A

SUPPLIERS

Addresses of suppliers having products mentioned in this document are given for information purposes only. Mention of a particular product or supplier does not constitute endorsement of that product or supplier.

Acurex Corporation
485 Clyde Avenue
Mountain View, CA 94042
(514) 964-3200

Associated Design and Manufacturing Company
814 North Henry Street
Alexandria, VA 22314
(703) 549-5999

J. T. Baker Chemical Company
222 Red School Lane
Phillipsburg, NJ 08865
(201) 859-2151

Balbab Incorporated
Division of Walter W. Platt Industries
6 Tinkam Avenue
Derry, NH 03038
(604) 434-4941

Millipore Corporation
Ashby Road
Bedford, MA 01730
(800) 225-1380

Nuclepore Corporation
7035 Commerce Circle
Pleasanton, CA 94566
(415) 462-2230

Pierce Chemical Company
P. O. Box 117
Rockford, IL 61105
(815) 968-0747

Wheaton Scientific
1000 North Tenth Street
Millville, NJ 08332
(609) 825-1400

APPENDIX B: STATISTICAL EVALUATION OF SOLID WASTE LEACHATE DATA

A statistical evaluation of experimental data generated from the SWLP is imperative to ensure the quality of interpretive information obtained from this procedure. As part of the development of the SWLP, a statistical model was developed for the purpose of analyzing the various components of error associated with the procedure.

Central to the concept of statistical evaluation of a leachate generation method is the analysis of a leachate "profile." Conceptually, leachate produced from a waste disposal site changes in composition over time. This process depicted in Figure B-1, where $\beta^*(t)$ is a function representing the activity of a chemical species. Laboratory analogs for producing this profile, which would take several years in the field environment, are designed to accelerate the release of chemical species through various extraction and leaching procedures.

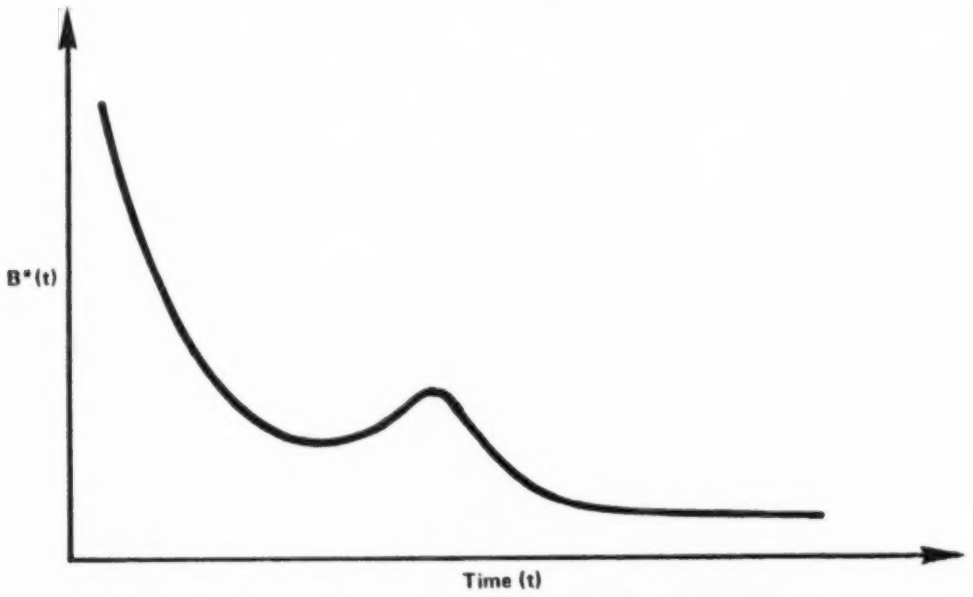

FIGURE B-1. A TYPICAL LEACHATE PROFILE ASSOCIATED WITH A SOLID WASTE

A leachate profile is characterized using the SWLP based on a series of batch extractions. This laboratory extraction procedure involves subsampling from a grab sample obtained from the waste, extracting the sample of waste, filtering to obtain a liquid filtrate and a solid filter cake, and finally analyzing the concentration of important analytes in the filtrate. The leaching process is repeated several times using the filter cake obtained from the previous trial to obtain a characteristic leachate profile for a given waste sample.

There are several important sources of experimental variation which can affect the results of this type of leachate generation method. Significant variation may be associated with (1) subsampling the grab sample of the organic waste, (2) the extraction procedure, and (3) the chemical analysis process. Sampling of the original waste is also recognized as a major source of experimental variation. However, for the purpose of this discussion, it can be assumed that a representative grab sample of the waste can be collected.

Objectives of the statistical analysis of data collected from an extraction method include:

(1) an estimation of the leachate profile function;

(2) a comparison of the leachate profile functions across different types of waste; and

(3) estimation of components of variation associated with waste sampling and extraction and chemical analysis.

These objectives can be accomplished through the use of a statistical model which characterizes the data generated by the extraction experiments. The statistical model is based on the assumption that a function $\beta(k)$ exists which, apart from uncontrollable experimental variation, determines the amount of analyte extracted from a sample with each successive extraction (k).

The function $\beta(k)$ describes only the deterministic mechanism affecting the leaching process at successive extraction number k. The complete statistical model also includes the error structure describing the important sources of experimental variability, such as subsampling, extractions, and chemical analysis. The level of detail required to completely describe the development of the appropriate form for $\beta(k)$ and the error structure is too complex to describe in this appendix.

A simplified version of the complete statistical model is a mixture of fixed and random effects and is given by:

$$Y_{ikn} = \beta(k) + S_i + \gamma_{ik} + \varepsilon_{ikn}$$

where

(1) Y_{ikn} is the observation recorded for the nth analysis for the kth extraction of the ith subsample of the waste;

(2) S_i is the random error due to subsampling;

(3) γ_{ik} is the random error due to extraction; and

(4) ε_{ikn} is the random error due to chemical analysis.

This usual distribution assumptions for the random model components are:

$$S_i \sim N\ (0,\sigma_S^2)$$

$$\gamma_{ik} \sim N\ (0,\sigma_L^2)$$

and

$$\varepsilon_{ikn} \sim N\ (0,\sigma_\varepsilon^2)$$

where $X \sim N\ (\mu,\sigma^2)$ indicates a random variable distributed normally with mean μ and variance σ^2.

Standard statistical techniques can be used to estimate the profile function $\beta(k)$ and the variance components σ_S^2 σ_L^2 and σ_ε^2. Since the total variance of the observed data Y_{ikn} is given by:

$$\sigma_Y^2 = \sigma_S^2 + \sigma_L^2 + \sigma_\varepsilon^2\ ,$$

the relative contribution of each source of variability to the total variability in Y can be estimated. For example, the percent relative contribution of subsampling to the total variation is given by:

$$RV(\text{Subsampling}) = \left[\sigma_S^2/\sigma_Y^2\right] \times 100.$$

Figures B-2 and B-3 and Table B-1 provide examples of the type of information which is obtained from the statistical analysis of a leaching method. Figure B-2 displays data obtained on the level of chromium contained in the leachate obtained from a 100 percent chromate waste for six successive extractions. The smooth curve superimposed on the data is the estimated leachate profile function $\beta(k)$.

Figure B-3 compares the leachate profiles for the analyte chromium extracted from a landfilled and a chromate waste. Table B-1 presents the estimates for the variance components and their relative contribution to the total variability for the two types of waste and for eight distinct analytes.

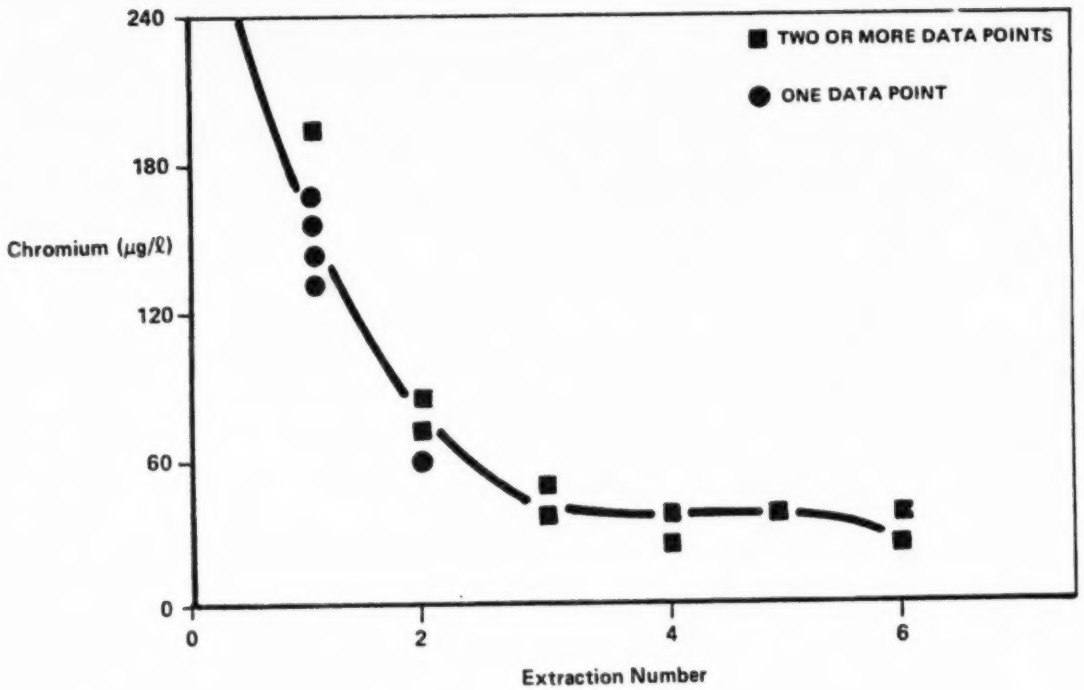

FIGURE B-2. LEACHATE PROFILE WITH DATA FOR 100% CHROMATE WASTE

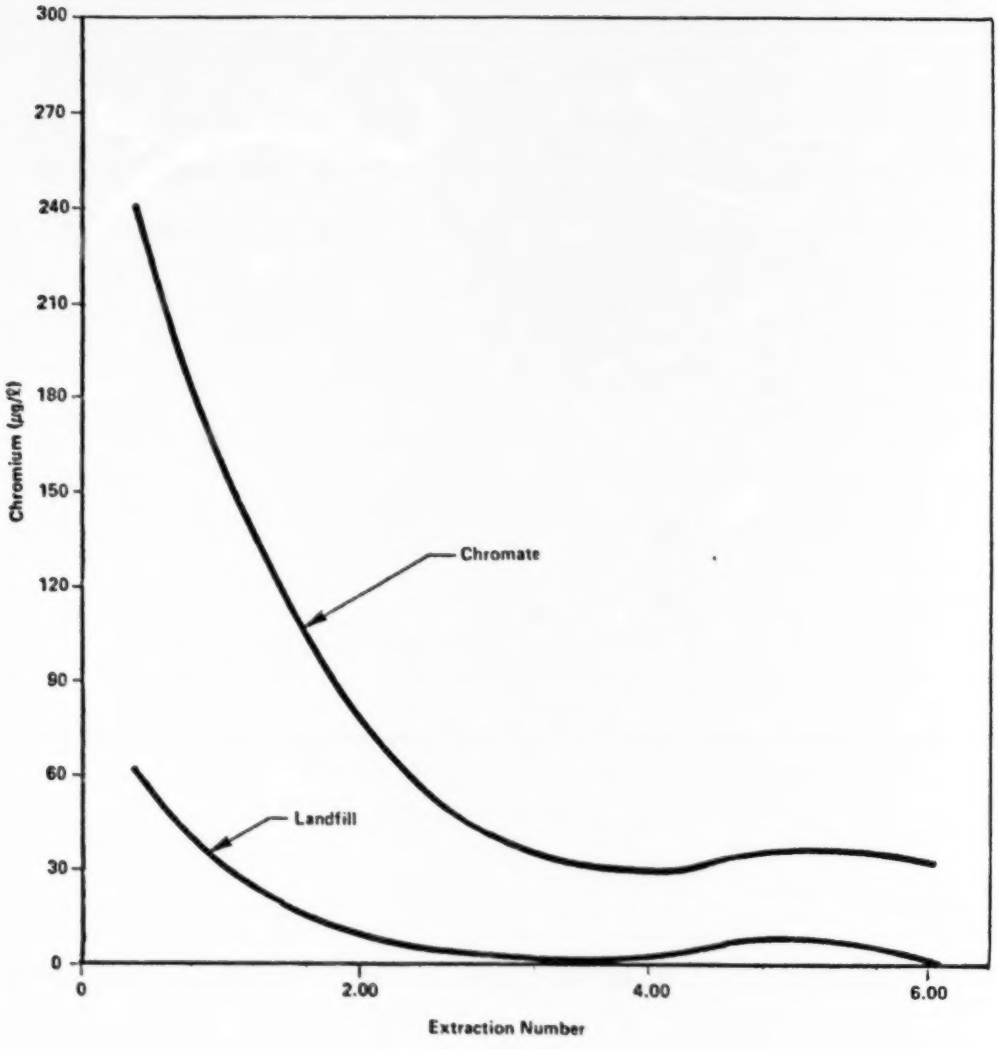

FIGURE B-3. COMPARISON OF 100% LANDFILL SOIL AND 100% CHROMATE WASTE PROFILES

TABLE B-1. ESTIMATES OF THE VARIANCES COMPONENTS AND PERCENT RELATIVE CONTRIBUTION FOR THE LANDFILL AND 100% CHROMATE WASTES.

ANALYTE	100% LANDFILL SOIL						100% CHROMATE WASTE					
	σ_S^2	(%)	σ_L^2	(%)	σ_ϵ^2	(%)	σ_S^2	(%)	σ_L^2	(%)	σ_ϵ^2	(%)
Boron	0.0	(0)	1.648	(58)	1.197	(42)	0.0545	(6)	0.3922	(43)	0.4680	(51)
Barium	0.0329	(4)	0.7552	(95)	0.0093	(1)	0.0	(0)	0.2837	(100)	0.0007	(0)
Calcium	0.0	(0)	0.1086	(91)	0.0101	(9)	0.0079	(37)	0.0134	(62)	0.0003	(1)
Chromium	0.0926	(9)	0.5048	(47)	0.4726	(44)	0.0007	(4)	0.0094	(56)	0.0066	(40)
Magnesium	0.0	(0)	0.0273	(97)	0.0008	(3)	0.0112	(38)	0.0177	(61)	0.0003	(1)
Sodium	0.4618	(4)	6.690	(61)	3.802	(35)	0.0	(0)	7.726	(81)	1.760	(19)
Strontium	0.0	(0)	0.0203	(97)	0.0007	(3)	0.0065	(36)	0.0111	(61)	0.0007	(4)
Zinc	0.0	(0)	1.706	(78)	0.4790	(22)	0.0	(0)	2.012	(78)	0.5588	(22)

This information is valuable in making comparisons between waste types and analytes. For example, from Figure B-3 it is clear that the leaching profiles for the landfilled and chromate wastes have similar shapes, but the level of chromium extracted from the landfilled waste is much less than from the chromate waste. Results in Table B-1 indicate that, in general, the greatest source of variability is due to the leaching procedure. In addition, the contribution of the subsampling to the total variation in the data appears to be greater for the chromate waste than for the landfilled waste.

Specific comparisons can also be made. For example, results shown in Table B-1 indicate that the error associated with the chemical analysis (σ_ϵ^2) for boron in the 100 percent chromate waste is significantly greater (51 percent on a relative basis) than that for calcium (1 percent on a relative basis).

APPENDIX C

COMPARISON OF LABORATORY AND FIELD LEACHATE COMPOSITION

The material in this appendix has been taken from reference 7 "Laboratory and Field Studies of Factors in Predicting Site Specific Composition of Hazardous Waste Leachate" by B. C. Garrett, J. S. Warner, M. P. Miller, and L. G. Taft.

Because of the need for data showing what correspondence previals between laboratory and field leachates, a study to provide samples allowing comparisons to be made was undertaken. Field leachates and groundwater samples were collected from an existing hazardous waste site, along with solid samples from selected bore-hole sites and depths. These solid samples were leached, and the laboratory and field leachates and groundwater samples were analyzed and compared.

The waste disposal site was used from 1953 to 1977, with the primary waste generator being a local manufacturer of pharmaceuticals. The site contains approximately 800,000 cubic meters (one million cubic yards) of chemical fill and contaminated underlying soils. Major chemical components estimated to have been disposed at this site are given in Table 1.

TABLE 1. ESTIMATED QUANTITIES OF MAJOR CHEMICAL COMPONENTS DISPOSED AT LANDFILL SITE

Compound[a]	Kg
Arsenic	2,740,000
1,1,2-Trichloroethane	32,000
Nitrobenzene	130,000
Orthonitroaniline	680,000
Phenol	12,000

a All but orthonitroaniline are priority pollutants

EPA Region VII ordered the primary waste generator to cease dumping and implemented remedial measures at the site. Among these measures was the placement of monitoring wells along the site perimeters. These wells were used during this study. The waste generator also drilled bore-holes into representative areas of the fill to determine the feasibility of in situ stabilization. Sites for these borings were chosen on the basis of prior studies of the geohydrology and chemical fill composition of this site. Core samples of chemical fill were obtained during the in situ stabilization feasibility assessment drilling.

Materials

Three types of samples were collected from the landfill site.

Groundwater

Groundwater samples were collected by site personnel from five monitoring wells: Well No. 4 - Alluvial, Well No. 6 - Alluvial Deep, Well No. 7 - Alluvial Shallow, Well No. 7 - Alluvial Deep, and Well No. 9 - Alluvial. Samples were stored at 4°C until prepared for analysis.

Chemical Fill Samples

Samples of the chemical fill were collected by means of a split spoon sampler at various depths from five bore-hold sites. Solid materials were transferred to glass containers, capped, and stored at 4°C pending analysis. These samples were leached in the laboratory to provide the laboratory leachate (see Procedure, below).

Field Leachate

Samples of leachate present with the waste fill were collected by means of a bailer from the freshly drilled holes. Bailer samples and additional bore-hole site information are given in Table 2. Four bore-holes provided samples of field leachate; a fifth site had no liquid. All bore-holes were capped followiing drilling and sampling.

Apparatus

Extractor

Chemical fill samples were leached using a rotary extractor (Associated Design and Manufacturing Company, Model #3740-4-BRE)*, which tumbled the sample plus water mixture in an end-over-end fashion.

*Manufacturers and suppliers are mentioned for identification purposes only. Mention of a particular brand or model does not constitute endorsement on the part of the U.S. EPA.

TABLE 2. LANDFILL BORE SITES

Bore Site	Date Drilled	Distance to Bottom of Chemical Waste (ft)	Distance to Water Table (ft)	Depth at Which Sample (Bailer) Taken (ft)	Comments
L-1-80	8 July 1980	23.5	22.5	23.0	Nothing remarkable
L-2-80	7 July 1980	18.5	--	--	Dry hole. No water, even after tornado of 9 July 1980.
L-7-80	9 July 1980	26.5	14.5	14.5	Copious amounts of water present in the core material
L-8-80	8 July 1980	21.0	24.5	24.5	Nothing remarkable
L-17-80	9 July 1980	13.0	23.5	29.5	Contained a strange whitish clay-like waste. Waste began within 6 inches of surfaces. Noticeable nitrobenzene ("shoe polish") odor from bore site.

Filtration Unit

Following tumbling, laboratory leachate samples were filtered using pressure filtration (Millipore Model #YT30-142-HW), in accordance with manufacturer's recommended procedure. This procedure required use of three types of filter pads: coarse glass fiber prefilter pad; fine glass fiber prefilter pad; and 0.45 micrometer nitrocellulose membrane filter. Groundwater and bailer field leachate samples were also filtered in an analogous procedure.

Inorganic Analysis

Filtrates from the laboratory leachate process and groundwater and field leachate samples were prepared for inorganic analysis by the digestion procedure given in Section 8.8.3, EPA Interim Method 200.7 (3). Digested samples were analyzed on a Jarrel Ash Model 965 Inductively Coupled Argon Plasma Spectrometer (ICAP). Low concentrations of arsenic were determined by the hydride generation technique, using a Perkin-Elmer Model 603 Atomic Absorption Spectrophotometer (AAS).

Organic Analysis

Samples were analyzed for organic constituents by gas chromatography (GC) and gas chromatography/mass spectrometry (GC-MS). Listings of substances suspected of having been disposed at this landfill site aided identification of mass spectra. GC and GC-MS operating conditions were: SE-52 glass capillary column, 30 meters long and with linear velocity of 50 cm/sec. Column oven conditions were 70° to 280°C at 4°/min, then hold at 280°C for 8 min. The gas chromatograph used as a Hewlett Packard Model 5730A equipped with a flame ionization detector. The GC-MS system was a Finnigan Model 3200 GC-MS/electron impact. Mass range of 40 to 450 mass units was searched at a scan rate of 1 to 2 sec. Identification was aided by a Finnigan/INCOS Library Search unit, using an NBS mass spectral library.

Leaching Procedure

Chemical fill samples from selected bore-hole depths were leached by the following procedures:

1. An "instantaneous" leachate was produced by tumbling 100 g chemical fill with 2.0 liters distilled, deionized water for approximately one minute. This rapid leaching was done to remove interstitial liquid that might represent field leachate that had migrated to, but was not characteristic of, the particular sample being leached.

2. The filter cake remaining after the separation of the instantaneous leachate through pressure filtration was leached by tumbling for 24 hours, using approximately 100 g filter cake with 2.0 liters water. The precise quantities of filter cake and water depended upon the amount of solid material remaining after the instantaneous leaching; however, the ratio of solid to liquid was maintained at 1:20 (w:v). This ratio was chosen to conform to that of the RCRA Extraction Procedure. However, experience gained since this work was performed suggests the use of lower ratios, such as 1:10 (2), is more appropriate.

Results

The analyses of the groundwater, field leachate (bailer), and laboratory-generated leachates are presented in Tables 3-6. Although the results are varied, the overall lack of agreement among the data for the three distinct sample types seems evident. This lack of correlation arises from more than just the dilution effects for the sample types, because correlation is also lacking within specimens of the same sample type, as shown by the disparity in the ratio of arsenic to orthonitroaniline (see Table 3). Both the concentrations and the multitude of constituents found differ between the field leachate (bailer) results and the laboratory leachates (bore-hole samples from similar depths), as shown for inorganic elements in Table 4 and organic compounds in Table 6.

TABLE 3. LANDFILL SAMPLES CONSTITUENT PROFILE - PRINCIPAL HAZARDOUS CONSTITUENTS

Sample Identification	Constituent			Ratio
	ONA[b]	PNA[c]	As[d]	As/ONA[e]
A. Well Samples				
4A	0.56[a]	ND	18.2	33
6AD	16	3.9	232	15
7AS	2.3	0.59	140	61
7AD	23	4.5	382	17
9A	65	18	336	5

(a) All results are in ppm (mg/l-solution)
(b) ONA = ortho-nitroaniline = 2-nitrobenzenamine
(c) PNA = para-nitroaniline = 4-nitrobenzenamine
(d) AS = arsenic
(e) As/ONA = ratio of As to ONA
ND = not detected

TABLE 3. (Continued)

Sample Identification	ONA			PNA			As			ONAs/ONA		
	1st	2nd	Liq	1st	2nd	Liq	1st	2nd	Liq	1st	2nd	Liq
B. Bailer and Solid Waste Leachate Samples												
1. Bore Site L-1												
3 ft	7.9	1.9	--	0.075	ND	--	2.5	1.8	--	0.3	0.9	--
14.5 ft	2.4	4.6	--	ND	ND	--	101	141	--	42	31	--
17 ft	0.40	0.52	--	ND	ND	--	2.6	8.4	--	7	16	--
Bailer (23 ft)	--	--	130	--	--	4.4	--	--	374	--	--	3
2. Bore Site L-2*												
21 ft	3.6	0.015	--	0.24	ND	--	14.2	1.4	--	4	93	--
22.5 ft	0.16	0.021	--	ND	ND	--	2.3	4.0	--	14	190	--
3. Bore Site L-7												
1.5 ft	26	27	--	0.26	0.32	--	7.2	14.2	--	0.3	0.5	--
16.5 ft	1.8	0.34	--	ND	ND	--	68.4	48.4	--	38	142	--
18 ft	1.9	0.24	--	ND	ND	--	35.6	24.8	--	19	103	--
18.5 ft	2.0	0.24	--	ND	ND	--	41.2	35.9	--	21	150	--
21 ft	3.1	ND	--	ND	ND	--	27.1	21.1	--	9	--	--
Bailer (14.5 ft)	--	--	16	--	--	ND	--	--	635	--	--	40
4. Bore Site L-8												
3 ft	2.6	1.1	--	ND	ND	--	2.0	3.4	--	0.8	3	--
17 ft	4.0	0.30	--	1.5	0.37	--	40.4	8.1	--	10	27	--
31 ft	ND	ND	--	ND	ND	--	0.9	1.4	--	--	--	--
Bailer (24.5 ft)	--	--	14	--	--	3.3	--	--	284	--	--	20
5. Bore Site L-17												
9 ft	ND	ND	--	ND	ND	--	5.6	4.2	--	--	--	--
9.5 ft	0.18	ND	--	ND	ND	--	12.0	5.6	--	67	--	--
21 ft	ND	ND	--	ND	ND	--	ND	ND	--	--	--	--
31 ft	ND	ND	--	ND	ND	--	ND	ND	--	--	--	--
Bailer (29.5 ft)	--	--	0.81	--	--	ND	--	--	64	--	--	79

NOTE: All results are in ppm (mg/l-solution)
1st = leachate generated by washing with H_2O for one minute, S:L = 1:20 (W/V)
2nd = leachate generated by 24 hour tumbling with H_2O, S:L = 1:20 (W/V)
Liq = liquid taken by means of the bailer
All other abbreviations are the same as part A above

* No bailer samples could be taken; dry bore hole

TABLE 4. LANDFILL SAMPLE CONSTITUENT PROFILE - GENERAL INORGANIC CONSTITUENTS
(Constituent (mg/l))

Sample Description	Al			Ca			Fe			Mg			Na			Zn			pH*
	1st	2nd	Liq	1st	2nd	Liq	1st	2nd	Liq	1st	2nd	Liq	1st	2nd	Liq	1st	2nd	Liq	
Well 4, Alluvial	--	--	0.1	--	--	399	--	--	0.05	--	--	34.5	--	--	20.2	--	--	0.13	7.48
Well 6, Alluvial Deep	--	--	<0.04	--	--	482	--	--	1.9	--	--	38.1	--	--	193	--	--	0.09	7.90
Well 7, Alluvial Shallow	--	--	0.05	--	--	162	--	--	0.18	--	--	10.6	--	--	42.4	--	--	0.22	7.03
Well 7, Alluvial Deep	--	--	0.06	--	--	423	--	--	0.32	--	--	26.6	--	--	205	--	--	0.08	7.12
Well 9, Alluvial	--	--	0.38	--	--	368	--	--	0.12	--	--	28.0	--	--	1700	--	--	0.11	7.37
1. Bore Site L-1																			
3.0 ft	0.73	0.21	--	9.4	7.0	--	0.95	0.28	--	1.5	0.9	--	5.9	<2	--	0.19	0.09	--	8.98
14.5 ft	<0.04	<0.04	--	599	630	--	0.04	0.05	--	2.4	1.4	--	14.5	<2	--	0.12	0.08	--	8.32
17.0 ft	0.17	0.11	--	10.3	586	--	0.06	0.03	--	0.2	0.5	--	16.4	<2	--	0.09	0.09	--	9.44
Bailer, 23.0 ft	--	--	284	--	--	2780	--	--	1280	--	--	126	--	--	94	--	--	5.3	7.96
2. Bore Site L-2																			
21.0 ft	0.06	0.15	--	595	7.0	--	0.06	0.07	--	0.5	0.1	--	41.0	<2	--	0.09	0.10	--	9.60
22.5 ft	0.07	0.16	--	6.4	5.9	--	0.14	0.25	--	0.2	0.2	--	5.4	2.7	--	0.10	0.08	--	7.31
3. Bore Site L-7																			
1.5 ft	<0.04	<0.04	--	580	608	--	0.07	0.03	--	2.1	1.7	--	<2	<2	--	0.06	0.07	--	8.44
16.5 ft	<0.04	0.07	--	587	592	--	<0.03	<0.03	--	7.4	2.1	--	24.3	<2	--	0.12	0.07	--	8.82
18.0 ft	<0.04	0.09	--	581	612	--	0.03	0.04	--	9.3	2.7	--	61.5	2.0	--	0.10	0.07	--	9.18
18.5 ft	0.05	0.12	--	570	594	--	0.05	0.04	--	9.8	1.6	--	77.8	3.0	--	0.05	0.06	--	8.70
21.0 ft	0.09	0.06	--	595	617	--	0.04	<0.03	--	2.0	2.2	--	77.9	2.7	--	0.09	0.04	--	9.04
Bailer 14.5 ft	--	--	11	--	--	3180	--	--	298	--	--	553	--	--	298	--	--	15.3	7.81
4. Bore Site L-8																			
3.0 ft	1.1	0.13	--	10.8	11.9	--	1.5	0.15	--	1.4	1.3	--	8.8	4.1	--	0.15	0.07	--	7.97
17.0 ft	0.08	0.09	--	620	602	--	0.03	<0.03	--	0.2	0.1	--	136	<2	--	0.13	0.20	--	9.66
31.0 ft	0.06	0.12	--	4.2	8.9	--	0.16	0.14	--	0.3	0.5	--	5.9	3.4	--	0.06	0.08	--	8.93
Bailer 24.5 ft	--	--	393	--	--	11400	--	--	1420	--	--	3080	--	--	650	--	--	2.7	8.04
5. Bore Site L-17																			
9.0 ft	0.07	<0.04	--	580	584	--	0.03	0.03	--	0.7	0.2	--	<2	<2	--	0.14	0.11	--	7.49
9.5 ft	<0.04	0.07	--	582	589	--	<0.03	<0.03	--	0.6	0.2	--	<2	<2	--	0.12	0.11	--	7.60
21.0 ft	0.58	0.35	--	1.8	0.8	--	0.57	0.38	--	0.2	0.1	--	<2	<2	--	0.12	0.14	--	7.61
31.0 ft	0.14	0.13	--	11.3	1.2	--	0.03	0.03	--	0.7	0.1	--	<2	<2	--	0.12	0.10	--	7.12
Bailer 29.5 ft	--	--	216	--	--	3190	--	--	494	--	--	65.4	--	--	15.9	--	--	1.7	7.75

NOTE: 1st = leachate generated by washing with H_2O for one minute, solid:liquid ratio = 1:20 (w/v)

2nd = leachate generated by 24 hour tumbling with H_2O in both cases, solid:liquid ratio = 1:20 (w/v)

Liq = liquid from well or bailer; * pH was determined for well, bailer, and 2nd leachate samples

TABLE 5. LANDFILL SAMPLE CONSTITUENT PROFILE - ORGANIC CONSTITUENT IDENTITIES

Five samples were analyzed by gas chromatography/mass spectrometry (GC/MS). The five were well 9 alluvial (W9A); well 9 alluvial-acidified (W9A (acid)); bailer from bore site L-8 (BL8); bailer from bore site L-17 (BL17); and the second leachate from the solid waste of bore site L-7 at 18.5 ft (X217d).

The number of important peaks (peaks having a significant peak count area and coming after the solvent peak) in the five samples ranged from five to twenty. The GC/MS data and a list of substances likely to be in the wastes were used to assign identities to the peaks.

Peak numbers are assigned according to relative retention times. Peaks for separate analyses having nearly the same relative retention time are given the same peak number. The identify of peak #9 for the well liquid samples does not match that assigned for peak #9 in sample X2L7d, a solid waste leachate.

Peak No.	Peak Identity	Samples for Which Peak Was Confirmed by GC/MS
1	aniline (benzenamine)	W9A, B18, BL17
2	phenol	W9A, W9A (acid), BL8
3	2-ethyl-1-hexanol	BL8, BL17
4	2-chloroaniline	W9A, W9A (acid), BL8
5	2-nitrophenol	W9A, W9A (acid), BL8
6	4-chloroniline	W9A (acid), BL8
7	ortho-phenylenediamine (1,2-benzenediamine)	W9A, BL8, BL17
8	2-chloro-4-methylaniline	W9A
9	2-butoxyethanol	W9A, W9A (acid)
9	1-chloro-2-methyl-3-nitrobenzene	X2L7d
10	ortho-nitroaniline (ONA)	W9A, W9A (acid), BL8, BL17, X2L7d
11	2-methylbenzimidazole	W9A
12	para-nitroaniline (PNA)	W9A, W9A (acid), BL8
13	diphenylamine	W9A, BL8, BL17, X2L7d
14	2-chloro-4-nitroaniline	W9A, W9A (acid)

TABLE 6. LANDFILL SAMPLE CONSTITUENT PROFILE - ORGANIC CONSTITUENTS

	Amount ONA (µg/ℓ)	Ratio of Peak Counts for Given Peak # to That of Peak # 10 (ONA) x 100 (a)														Number of Peaks Detected
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Well 4, Alluvial	0.56	ND	ND	ND	ND	ND	ND	ND	ND	ND	100	ND	ND	ND	ND	1
Well 6, Alluvial-Deep	16	ND	177	ND	ND	ND	21	1.5	1.6	ND	100	ND	26	ND	0.7	7
Well 7, Alluvial-Shallow	2.3	ND	77	ND	ND	ND	15	ND	ND	ND	100	ND	28	ND	ND	4
Well 7, Alluvial-Deep	23	ND	106	3.6	0.5	ND	ND	80	2.8	ND	100	4.0	22	ND	ND	8
Well 9, Alluvial	65	6.7	5.4	ND	0.4	1.0	5.9	0.6	0.4	0.8	100	4.6	30	1.1	5.2	13
Well 9, Alluvial (acidified)	69	ND	6.1	ND	0.4	1.1	0.6	ND	0.3	0.8	100	1.9	103	ND	4.6	10
1. Bore Site L-1																
3.0 ft 1st	7.9	ND	--	--	--	--	--	--	--	--	100	--	1.0	--	--	2
3.0 ft 2nd	1.9	ND	--	--	--	--	--	--	--	--	100	--	--	--	--	1
14.5 ft 1st	2.4	ND	--	--	--	6.0	--	--	--	--	100	--	--	--	--	2
14.5 ft 2nd	4.6	ND	--	--	--	3.1	--	--	--	--	100	--	--	--	--	2
17.0 ft 1st	0.40	ND	--	--	--	--	--	--	--	--	100	--	--	--	--	1
17.0 ft 2nd	0.52	ND	--	--	--	--	--	--	--	--	100	--	--	--	--	1
Bailer, 23.0 ft	130	ND	2.0	0.6	ND	3.8	ND	<0.1	0.2	ND	100	ND	3.7	ND	3.7	8
2. Bore Site L-2																
21.0 ft 1st	3.6	--	--	--	--	1.0	--	--	--	--	100	--	6.0	--	--	3
21.0 ft 2nd	0.015	--	--	--	--	--	--	--	--	--	100	--	--	--	--	1
22.5 ft 1st	0.16	--	--	--	--	--	--	--	--	--	100	--	--	--	--	1
22.5 ft 2nd	0.021	--	--	--	--	--	--	--	--	--	100	--	--	--	--	1
3. Bore Site L-7																
1.5 ft 1st	26	--	--	--	--	--	--	--	--	--	100	--	0.5	--	--	2
1.5 ft 2nd	27	--	--	--	--	--	--	--	--	--	100	--	0.6	--	--	2
16.5 ft 1st	1.8	--	--	--	--	--	--	--	--	40	100	1.6	--	71	--	4
16.5 ft 2nd	0.34	--	--	--	--	--	--	--	--	149	100	--	--	1100	--	4
18.0 ft 1st	1.9	--	--	--	--	--	--	--	--	48	100	--	--	82	--	3

(a) Peak # refers to that number given in Table 5.

TABLE 6. (Continued)

	Amount ONA (μg/ℓ)	Ratio of Peak Counts for Given Peak # to That of Peak # 10 (ONA) x 100 [a]														Number of Peaks Detected
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	
3. Bore Site L-7 (Continued)																
18.0 ft 2nd	0.24	--	--	--	--	--	--	--	--	231	100	--	--	2800	--	3
18.5 ft 1st	2.0	--	--	--	--	--	--	--	--	44	100	--	--	62	--	3
18.5 ft 2nd	0.24	--	--	--	--	--	--	--	--	246	100	--	--	2700	--	3
21.0 ft 1st	3.1	--	--	--	--	--	--	--	--	2.1	100	3.8	5.6	20	2.4	6
21.0 ft 2nd	ND	--	--	--	--	--	--	--	--	--	0	--	--	--	--	0
Bailer, 14.5 ft	16	ND	ND	ND	ND	ND	ND	ND	ND	ND	100	ND	ND	17	ND	2
4. Bore Site L-8																
3.0 ft 1st	2.6	--	--	--	--	--	--	--	--	--	100	--	--	--	--	1
3.0 ft 2nd	1.1	--	--	--	--	--	--	--	--	--	100	--	--	--	--	1
17.0 ft 1st	4.0	--	3.4	9.8	--	14	--	0.6	--	--	100	--	29	6.5	--	7
17.0 ft 2nd	0.30	--	--	--	--	7.4	--	--	--	--	100	--	97	99	--	4
31.0 ft 1st	ND	--	--	--	--	--	--	--	--	--	0	--	--	--	--	0
31.0 ft 2nd	ND	--	--	--	--	--	--	--	--	--	0	--	--	--	--	0
Bailer, 24.5 ft	14	17	19	28	3.4	7.2	15	1.2	0.7	ND	100	ND	26	3.9	ND	11
5. Bore Site L-17																
9.0 ft 1st	ND	--	--	--	--	--	--	--	--	--	0	--	--	--	--	0
9.0 ft 2nd	ND	--	--	--	--	--	--	--	--	--	0	--	--	--	--	0
9.5 ft 1st	0.18	--	--	--	--	--	--	--	--	--	100	--	--	--	--	1
9.5 ft 2nd	ND	--	--	--	--	--	--	--	--	--	0	--	--	--	--	0
21.0 ft 1st	ND	--	--	--	--	--	--	--	--	--	0	--	--	--	--	0
21.0 ft 2nd	ND	--	--	--	--	--	--	--	--	--	0	--	--	--	--	0
31.0 ft 1st	ND	--	--	--	--	--	--	--	--	--	0	--	--	--	--	0
31.0 ft 2nd	ND	--	--	--	--	--	--	--	--	--	0	--	--	--	--	0
Bailer, 29.5 ft	0.81	162	ND	113	ND	ND	ND	66	ND	ND	100	ND	ND	86	ND	5

These results demonstrate that laboratory-generated leachates of samples from an existing site cannot be used readily to gain an accurate profile of the field leachate or groundwater quality associated with that site. The reasons for this apparent lack of correlation include:

- Field leachate may have migrated from elsewhere and is co-present with, but not indicative of, the chemical fill; consequently, samples taken from the fill were not indicative of that portion of the fill responsible for the field leachate.

- Leaching process used in the laboratory was not representative of the field leaching environment.

- Chemical fill materials had lost the most soluble or readily leached constituents and, hence, any further leaching could not reproduce the field leachate composition.

The lack of correlation for this single case does not preclude use of leaching tests for all other sites. These results do demonstrate the need for careful site analysis during interpretation of laboratory data.

Landfill conditions that should be considered include age of waste, amount of prior moisture infiltration, and initial waste composition. For many existing landfills, some of this information cannot be determined; and laboratory leaching of small samples taken from landfills that are of unknown initial composition and have undergone unknown field leaching seems unpromising as a means for predicting genuine field leachate composition or potential threat to groundwater.

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